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Illuminating Engineer

XVIII. April, 1935 Price 9

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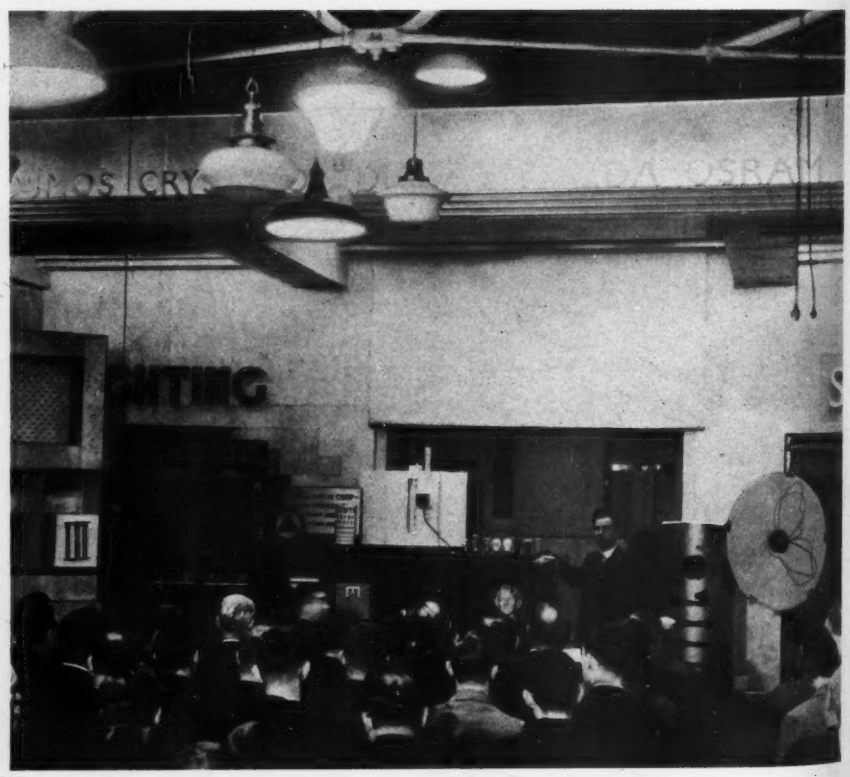

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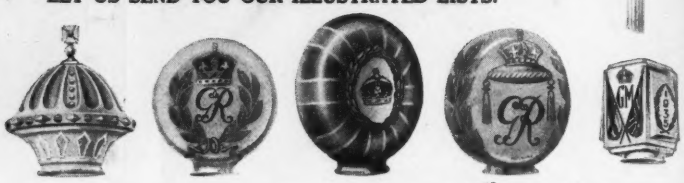

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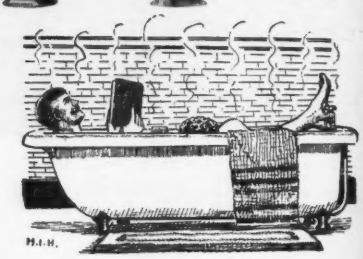

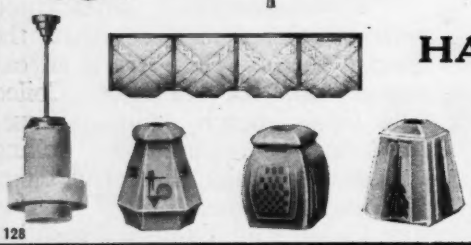

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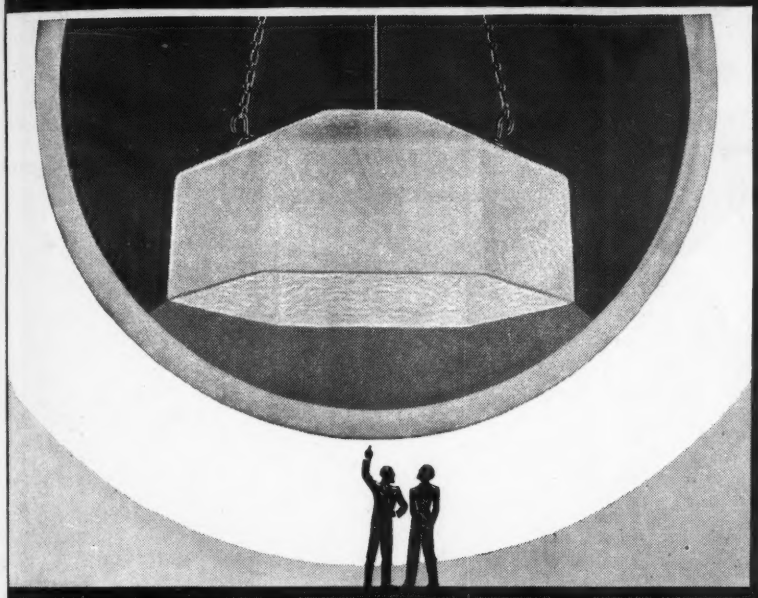

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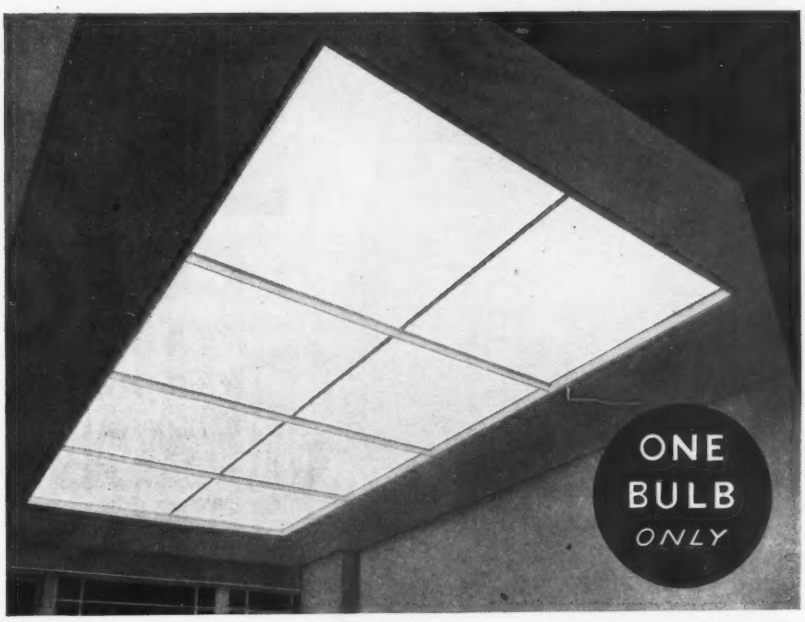

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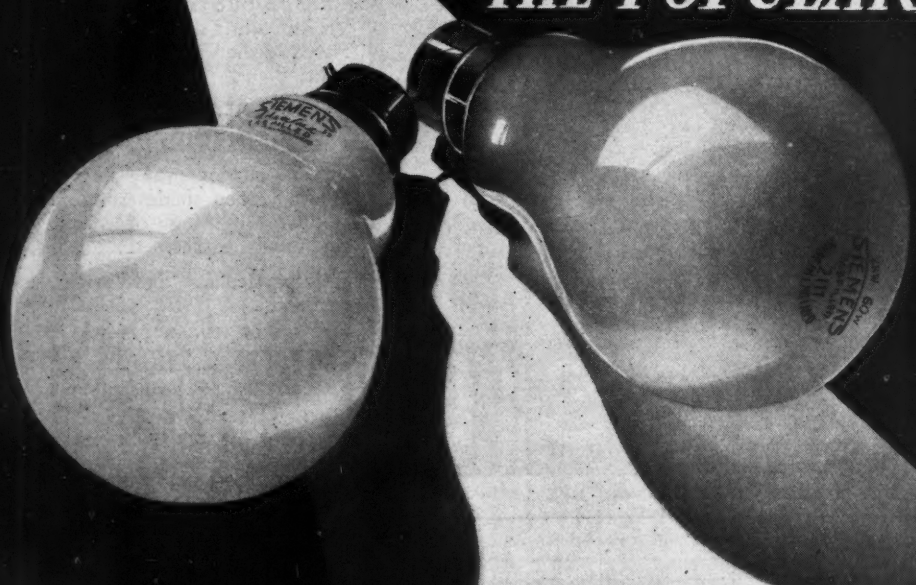

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Official Journal of THE ILLUMINATING ENGINEERING SOCIETY
FOUNDED IN LONDON 1909
INCORPORATED 1930

The ILLUMINATING ENGINEER

THE JOURNAL OF GOOD LIGHTING

Edited by

J. STEWART DOW

Official Journal of THE ASSOCIATION of PUBLIC LIGHTING ENGINEERS
FOUNDED 1923
INCORPORATED 1928

Vol. XXVIII
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The Jubilee Decorations

ON this subject two schools of thought exist.

There are those, like Mr. C. R. W. Nevinson, who desire the whole scheme planned on harmonious artistic lines by expert bodies such as the Royal Academy.

There are others who uphold the view expressed recently in "*Signs*" that those who pay the bill for decorating or illuminating their own premises are entitled to express their ideas in their own way; that the decorations should be "a spontaneous expression of the patriotic feeling and loyalty of those who are responsible for them."

Most people will agree.

In any case it seems impracticable to organise and co-ordinate a widespread effort of this kind—though doubtless the floodlighting of important public buildings will be subject to supervision. Here the experience of 1931 should be helpful in enabling results at once pleasing and dignified to be obtained.

This once achieved we trust that the installations will be put on a permanent basis, so as to be available on any appropriate occasion in the future.

Glare From Motor Headlights

A contribution to the study of this perennial (or shall we say hardy annual?) problem is afforded by Dr. W. S. Stiles and Mr. C. Dunbar in a recently issued Report.*

Those familiar with the scientific thoroughness characteristic of the work of Dr. Stiles will not be surprised to learn that the report is a somewhat lengthy one (occupying in all 88 pages). We hope, however, that designers of motor-car headlights will not be deterred by this, nor by the occasional mathematical equations. They will find it worth while to study this very interesting method of assessing freedom from glare based not merely on impressions of stationary headlights, but on experience on the roadway, when glare or dazzle is caused by the headlights of passing cars. The authors do not attempt to produce a model headlight. They do, however, show how figures of merit may be computed and how allowance may be made for the numerous incidental disturbing factors, such as oscillations of the car due to uneven road surfaces. As examples, figures of merit are worked out for several alternative types, namely, a simple headlight employing no anti-dazzle device, a dipped and swivelled headlight, and a headlight giving a flat-topped beam. Besides congratulating the authors on their investigation, we should also like to commend H.M. Stationery Office and the Department for the admirable popular summary with which the Report is accompanied. We have always held that scientific reports of any complexity should be assisted by aids of this nature, enabling the non-technical to see at a glance " what it is all about."

Efficiency of Light Production

L. J. Buttolph, in a recent contribution to the Transactions of the Illuminating Engineering Society (U.S.A.) (Feb., 1935, p. 160), gives some interesting figures for the efficiency of illuminants. An ideal white light (380-700mm. only) would furnish 220 lumens per watt, and monochromatic yellow light (555mm.) as much as 620 lumens per watt. In fact, actual sunlight furnishes 100 lumens per watt. Of the most efficient electric sources the sodium arc (45), the high-pressure mercury arc (32), and the incandescent 500-watt lamp (20 lumens per watt) stand highest.

* " The Evaluation of Glare from Motor-car Headlights," Dept. of Scientific and Industrial Research, Tech. Paper No. 16, available from H.M. Stationery Office, 1s. 6d. net.

Standard Study Lamps

A well-shaded and well-designed portable table lamp has great advantages, but the utility of such lamps is much diminished if certain fundamental points are neglected. It is essential that (1) the source should be screened from the eye, (2) the illumination on the reading area should be adequate, and (3) this illumination should be reasonably uniform and free from streakiness. The American Illuminating Engineering Society, rather less than a year ago, issued a specification for a standard 100-watt study lamp. The standard was somewhat higher than usual and the lamp furnished 20-40 foot-candles on the working area, with absence of glare and negligible shadows. The brightness of the visible surface did not exceed three candles per square inch, and the shade, being open at the top, furnished a useful indirect component for general lighting. Lamps designed to comply with the specification were furnished with a special label recording the fact. The expediency of thus taking responsibility for fittings would probably be regarded as somewhat questionable by the Society in this country. It is well, however, that the main requirements in a table lamp—so often used by students—should be clearly stated. The most common mistake is to make the lamp too low, so that very uneven illumination results. Care should be taken to ensure good diffusion. For this reason internally frosted electric lamps are to be preferred to those with clear bulbs.

Combination Fittings For Incandescent and Electric Discharge Lamps

A correspondent draws our attention to a serviceable combined unit, a (mercury) gas-filled lamp surrounded by three incandescents and housed within a cylindrical opal shade, which has been installed near the Archway Tavern in North London. This unit, mounted as it is at a considerable height, effectively illuminates this extensive and busy traffic spot, where five busy roads converge. The colour of the mixed light is quite agreeable. Our correspondent, however, raises one interesting query—what would happen in the event of a momentary breakdown in the supply? When current is restored the incandescent lamps would light up. Is it possible that, if the interval was short, their heat would prevent the discharge lamp from cooling sufficiently to start up again? The problem is an interesting one though the contingency seems rather remote; one doubts whether, in such a fitting as this, the cooling of the central discharge lamp could be appreciably affected.

TECHNICAL SECTION

COMPRISING

Transactions of The Illuminating Engineering Society and Special Articles

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

The Illuminating Engineering Society

Notes on Recent Meetings & Events

Meeting in London, March 12.

A JOINT Meeting of the Illuminating Engineering Society and the Royal Aeronautical Society took place in the Lecture Theatre of the Institution of Mechanical Engineers (Storey's Gate, Westminster, S.W.1) on Tuesday, March 12. Members assembled for light refreshments at 6.30 p.m. The chair was taken by the President (Mr. H. Hepworth Thompson) at 7.0 p.m., who extended a cordial welcome to the members of the Royal Aeronautical Society who were present.

The minutes of the last meeting having been taken as read, the Hon. Secretary read out the list of names of applicants for membership, which is appended. The names of those present at the last meeting on February 19* were again read, and these gentlemen were formally declared members of the Society. The Hon. Secretary drew attention to the addition of a number of members in Dublin, where much interest is now being taken in the work of the Society.

The President then called upon Mr. H. N. Green to present his paper on "Recent Developments in Airway and Aerodrome Lighting."

The paper reviewed requirements in regard to beacons, suggesting that lower power beacons close together marked a route better than beacons of higher power relatively far apart. The design of airway floodlights (in which substantial progress has recently been made), boundary lights, etc., was also discussed and some indication of recent Continental practice was given.

The subsequent discussion was opened by Major R. Mealing (who had read a paper on this subject before the Society some years ago). Others who took part included Mr. Percy Good, Mr. E. Gordon England, Mr. Oliver Simmonds, M.P., Dr. W. M. Hampton, Mr. W. A. Villiers, and Mr. J. S. Dow. After Mr. Green had briefly replied to the discussion a cordial vote of thanks to the author terminated the proceedings.

* Illum. Eng., Mar., 1935, p. 67.

Applicants for Membership.

CORPORATE MEMBERS:—

Fuller, V. G. .....74, Hurstwood Road, Golders Green, LONDON, N.W.11.

Haynes, T. S. Lyndon 24, College Court, LONDON, W.6.

Hudson, H. F. .....Gas Light & Coke Company, York Road, SOUTHEND.

Shrimpton, A. H. ...Gas Light & Coke Company, 1, Avondale Mansions, Rostrevor Road, LONDON, S.W.6.

Thomas, H. L. .....Sperry Gyroscope Company, 63, Iffley Road, LONDON, W.6.

Turrell, F. N. .....Gas Light & Coke Company, 40, Victoria Avenue, HOUNSLOW.

Weston, H. C. ....."Inverclyde," The Avenue, Orpington, KENT.

COUNTRY MEMBERS:—

Byrne, J. .....28, Bantry Road, Whitehall, DUBLIN.

Catling, J. E. .....49, Hagley Road, Edgbaston, BIRMINGHAM.

Creagh, J. .....11, Ashbrook Villas, Ashbrook House, Sallymount Avenue, Ranelagh, DUBLIN.

Johnston, W. C. .....12-13, Eustace Street, DUBLIN.

McBride, T. J. .....328, Griffith Avenue, Whitehall, DUBLIN.

MacCormack, C. E....93, Kenilworth Park, DUBLIN.

Reilly, E. O. .....49, Dartmouth Square, DUBLIN.

Turvey, W. L. .....5, The Mount, ST. LEONARDS-ON-SEA.

Wingfield, G. G. .....The Larches, Tytherington, Falfield, GLOS.

AFFILIATED STUDENT:—

Ridley, C. F. .....Nutley Garage, High Street, NUTLEY.

(The paper by Mr. H. N. Green and the ensuing discussion will appear in our next issue.)

The Best Time for Meetings

The experience of the Illuminating Engineering Society in regard to the best time for meetings should be instructive to other bodies, as the Society's membership is unusually varied as regards occupation, and also covers a wide range in regard to age. For some years it has been the custom for meetings to be held on Tuesday evenings, at 6.30 p.m. for 7 p.m., but as there seemed to be a disposition to raise once more this oft-debated question, it was thought expedient to ascertain the general opinion by means of a postcard vote. Members were offered the choice of four days, Tuesday, Wednesday, Thursday and Friday (the week-end days being obviously unsuitable), and three alternative times of meeting, namely, 6 to 8 p.m., 7 to 9 p.m. (the existing period), and 8 to 10 p.m. Members were also asked to indicate both the days and times that were *preferable* and those that were *impossible* for them. In regard to the choice of day the vote was overwhelmingly in favour of Tuesday. In regard to time of meeting only eight votes were cast for 8 to 10 p.m., whilst those cast in favour of the other two periods were exactly equal! It appeared, however, that more members found 6 to 8 p.m. impossible than the later period. Moreover, when the vote was taken, members were informed that if no voting card was returned, the recipient would be understood to approve the existing practice. On balance, therefore, it was evident that the prevailing view favoured the existing meeting time, namely, 7 to 9 p.m. on Tuesday. The preference for Tuesday is no doubt readily explained by the fact that meetings of other societies and institutions, to which many members of the Illuminating Engineering Society also belong, take place on other days. In regard to time of meeting, however, it seems quite clear that relatively late hours are definitely unpopular. People prefer to reach home at a comparatively early hour; they also, in many cases, dislike a long period of waiting between the time of leaving their office and the time when the meeting commences.

Forthcoming Events.

April 9. Contributions on (i) **A Works Photo-electric Method for the Photometry of Electric Discharge Lamps** (P. D. OAKLEY); (ii) **A Simple System for Recording and Displaying Measurements of Illumination** (R. R. HOLMES); (iii) **The Use of Scale Models in Illuminating Engineering** (H. S. BARLOW); (iv) **Practical Considerations in Architectural Lighting** (H. LINGARD) *(Meeting of the Illuminating Engineering Society, to be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.);* **6.30 p.m.**

April 10. A Discussion on **Problems in Street Lighting** will be opened by Mr. C. A. MASTERMAN *(Meeting of the North-West Area Local Section of the Illuminating Engineering Society, to be held in the Engineer's Club, Albert Square, Manchester).* **7.30 p.m.**

April 16. Visit of Members of the Illuminating Engineering Society to the **Glyndebourne Festival Opera House,** Lewes, Sussex. *(Members desiring to take part should notify the Hon. Secretary by April 10th); Departure from Victoria Station* **3.10 p.m.**

May 14. Annual Meeting. After the transaction of formal business an **Address** by PROFESSOR DR. M. PIRANI (Berlin). *(Meeting of the Illuminating Engineering Society to be held at the Institution of Mechanical Engineers, Storey's Gate, Westminster, S.W.);* **6.30 p.m.**

Association of Public Lighting Engineers

12th Annual Meeting and Conference London, Sept. 9-12, 1935

The above Conference is this year to be held in London. The Association is thus returning to the City in which its first annual conference was held rather more than ten years ago. Every effort will be made to make the forthcoming conference an outstanding success. Opportunities of studying the chief features of the lighting of London will be afforded. The usual Annual Report surveying progress in public lighting throughout the country will be presented. An interesting series of papers dealing with various phases of street lighting is now being prepared. There will be numerous agreeable social events. The headquarters of the Association will be at the Hotel Metropole (Northumberland-avenue, W.C.), where all meetings will take place.

The registration fee for one or more delegates attending from a local authority is two guineas. No registration fee is required from members or associates of the A.P.L.E. A special invitation is being extended to members of the Illuminating Engineering Society to attend this coming Conference at a special registration fee of half a guinea per person.

Recent Developments in Street Lighting in Relation to Safety

We understand that a paper on the above subject has been promised by Mr. S. B. Langlands for the special session being arranged in connection with the Annual Conference of the National Safety First Association, to take place this year in London. This session, which will receive the joint support of the Illuminating Engineering Society and the Association of Public Lighting Engineers, will take place on the afternoon of May 31. It is hoped that a good number of members of both bodies will be able to attend.

We also understand that road engineers will be meeting to consider problems connected with road-surfacing. We hope that some of them, too, will attend the discussion of the above paper, which will, no doubt, contain some reference to the important part played in street lighting by the light-reflecting properties of the surfaces of roads.

Illumination and Visibility as Factors in Scientific Management

We are informed that a paper with the above title, by Major H. C. Gunton and Mr. H. C. Weston, is to be presented at the Sixth International Congress for Scientific Management, which meets in London during July 15-20. This paper, which is presented under the auspices of the Illuminating Engineering Society, will refer to some recent work of the National Illumination Committee on factory lighting, and will doubtless have a useful influence in bringing the claims of good lighting before the notice of the many representatives of industrial undertakings who will be coming to London for this event.

The Time Characteristics of Tungsten Filament Lamps for Signs, Signals & Beacons

COMMUNICATION No. 168

By J. M. SANDFORD and J. M. WALDRAM, B.Sc., A.C.G.I., F.Inst.P.

(A communication from the Staff of the Research Laboratories of the General Electric Company, Ltd., Wembley, England; presented at the meeting of the Illuminating Engineering Society, held at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6.30 p.m., on Tuesday, February 19th, 1935.)

Introduction.

In the design of special illuminating equipment, particularly of signals and beacons, it is sometimes necessary to produce a flashing indication. The straightforward way is to interrupt the lamp circuit, and the designer immediately requires data of the time characteristics of the available lamps. For if they are unsuitable for giving a clear indication in this way, and if it is necessary to produce a flashing characteristic by some other means, the whole design of the apparatus is fundamentally altered and greatly complicated.

The need for data of this sort prompted the present research. Our intention was not to repeat any previous work, but to attempt to extend existing knowledge to cover a comprehensive range of modern tungsten filament gas-filled lamps.

Much of the ground has been ably covered, from both the theoretical and the practical standpoints, by Forsythe and Worthing* and others. Their experimental work was, however, limited to a few special lamps, and it is a tedious matter to calculate from their formulae the incandescence and nigrescence curves to be expected from a given lamp. Moreover, knowledge of filament data is necessary which is not easily available. Assumptions have also to be made, the justification for which is not too certain for modern lamps. It was felt, therefore, that experimental data for actual lamps would be valuable and far more simple to use.

The data and conclusions which follow have, therefore, been drawn solely from a study of a large amount of experimental work on lamps available on the market. No attempt has been made to extract any but the simplest of empirical formulae from the data presented, with the intention that these formulae would be easily and simply applicable to many of the present-day problems which involve knowledge of the time characteristics of lamps. A sufficiently large range of lamps has been tested to cover the whole current range used in lamp manufacture.

1. General Considerations.

When a tungsten filament lamp is switched on and off it does not respond instantaneously. It requires a definite time interval after switching on, during which the filament heats up to its running temperature, and a further period after switching off during which it cools to room temperature. These periods, which for large lamps may be a matter of seconds, are known as the incandescence and nigrescence periods respectively: the curve connecting the relative intensity of the lamp with time after switching on or off is referred to in this paper as the incandescence or nigrescence curve.

When a cold lamp is switched on, the initial instantaneous current is high, owing to the low resistance of the filament, and the power input is correspondingly high. Heat is immediately generated and the filament temperature rises; simultaneously, the resistance increases and the current falls. Worthing has pointed out that at any instant the power input into the filament is equal to the rate of loss of heat by radiation, conduction, and convection, plus the rate of storing heat in the filament.

A consideration of the quantities concerned leads to the conclusion that the most important factor in determining the rate of heating and cooling is the diameter of the filament, and hence the current rating of the lamp. Other factors, such as the amount of end cooling and support losses, spiralling constants, nature of gasfilling, and efficiency rating have secondary effects.

The characteristics of the circuit supplying the lamp can also greatly affect the incandescence time.

2. Method of Measurement.

The method of measurement employed was a photoelectric equivalent of that used by Worthing,* to which reference has already been made. The most obvious and possibly preferable method, namely, the use of a photoelectric cell, amplifier, and oscillograph, was inconvenient (for various reasons), and the necessary apparatus for the method adopted was more readily available. The circuit is shown in Fig. 1, mechanical parts being diagrammatic.

The principle of the method is as follows:—The test lamp was switched on and off periodically by

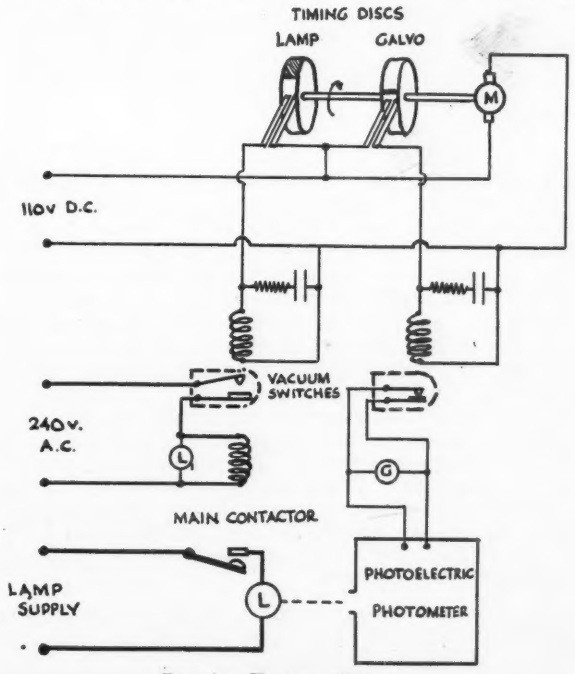

Fig. 1. Testing Circuit.

* See particularly Worthing, Jour. Frankl. Inst., 191, p. 231.

* Worthing, J. Frankl, Inst., 191, p. 231.

a contactor controlled by a contact on a rotating disc. The on and off periods were equal, and one on-off cycle occupied one revolution of the disc. Light from the lamp was allowed to fall on the cell of a photoelectric photometer, in which a volt drop due to the photoelectric current was amplified and balanced on a potentiometer. The galvanometer was normally short-circuited by a relay which was opened momentarily by a contact on a second rotating disc on the same axis as the disc controlling the lamp, but capable of known phase displacement relatively to it. In this way the short circuit to the galvanometer was removed momentarily at a known time after the circuit of the test lamp had been made or broken. If the potentiometer was not so set as to balance the photoelectric e.m.f. at the instant of contact, the galvanometer would "kick" in one direction or the other, and it was found possible to balance the potentiometer with sufficient accuracy by adjusting to the point of minimum "kick." In practice, the galvanometer was generally found to kick slightly in either direction when the potentiometer was balanced. By taking a series of readings of the potentiometer at different relative settings of the timing discs, i.e., at different known time intervals after switching the lamp on or off, the complete incandescence and nigrescence curve for the lamp could be determined.

Apparatus.

(*i.*) *Timing Discs.*—A photograph of the timing discs is shown in Fig. 2. They consisted of two

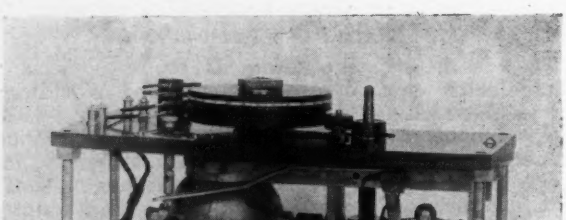

Fig. 2. Timing Discs.

coaxial ebonite discs 3 in. diameter and ½ in. thick which could be clamped together, and which rotated as a single unit, being driven by a special 3-speed friction drive from an electric gramophone motor.* The speed of the discs was checked stroboscopically from a neon lamp run on the 50 cycle A.C. mains.

One disc, used for the control of the lamp, carried a brass insert extending over one half of its circumference, and the other carried a small insert about ¼ in. long. The latter disc also carried a scale marked in hundredths of a second on which the relative positions of the discs, and therefore the timing of the galvanometer contact, was read against a mark on the other disc. The duration of the galvanometer contact could be varied by moving one of the brushes relatively to the others, which had the same effect as decreasing the width of the small brass insert controlling the contact.

(*ii.*) *Contactors.*—For the control of the smaller lamps and for the short circuiting of the galvanometer, two experimental vacuum switches were used.

For larger lamps the vacuum switch was used to control a normal (100 amp.) contactor, placed outside the laboratory to avoid noise. The overall time lag of this contactor system was determined and allowed for.

(*iii.*) *Photoelectric Photometer.*—The photoelectric photometer finally used was one designed by Mr. G. T. Winch for use as a spectrophotometer, a description of which is in course of publication.

In this photometer the photoelectric unit consisted of an evacuated glass tubular envelope containing a KMV6 photocell having a plane rectangular cathode, a grid leak, and an electrometer triode arranged in a conventional valve bridge amplifier. In this circuit the voltage drop across a grid leak produced by the photoelectric current is balanced out by voltage from a Tinsley potentiometer. The circuit is given in Fig. 3. The photoelectric unit, batteries,

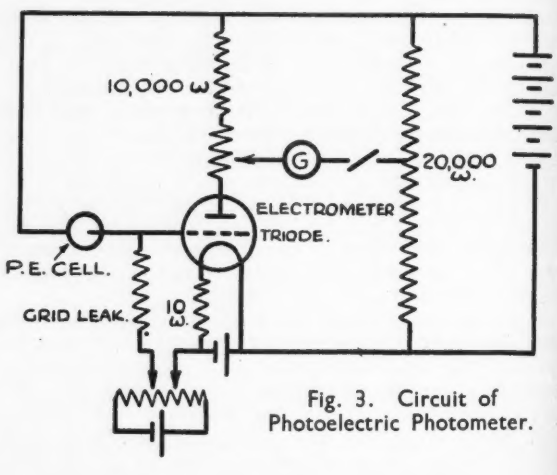

Fig. 3. Circuit of Photoelectric Photometer.

standard cell, and potentiometer were contained in screened compartments in a metal box. The window through which light entered was provided with an iris diaphragm and shutter, so that the light could be controlled and cut off at will. Simple means for checking the zero were arranged. The amount of light reaching the cell was adjusted to give a conveniently high reading when the lamp was burning steadily.

Duration of Galvanometer Contact.—The duration of the galvanometer contact was important. If it were long the sensitivity was improved, but the current through the galvanometer was changing so rapidly during the period of the contact that an uncertainty existed as to the instant of time represented by the reading. On the other hand, if the duration of the contact were very short the balance point was uncertain because the sensitivity was low. After experiment a duration of 0.01 seconds was used, the total cycle time being either 3 or 6 seconds.

Photometric Response.—The linearity of response was investigated by making observations with the photoelectric photometer of a lamp run on a series of steady D.C. voltages, the voltage intensity relationship being known. Satisfactory agreement was found, as shown by Fig. 4, which was obtained with a cruder form of the apparatus.

3. Results.

Incandescence and Nigrescence Curves.

Sixteen lamps in all were tested, their ratings being selected to cover as wide a range as possible of the various types and classes of gas-filled lamps at pre-

* J. M. Waldram and J. M. Sandford, J. Sci. Instr., 1934. p. 26.

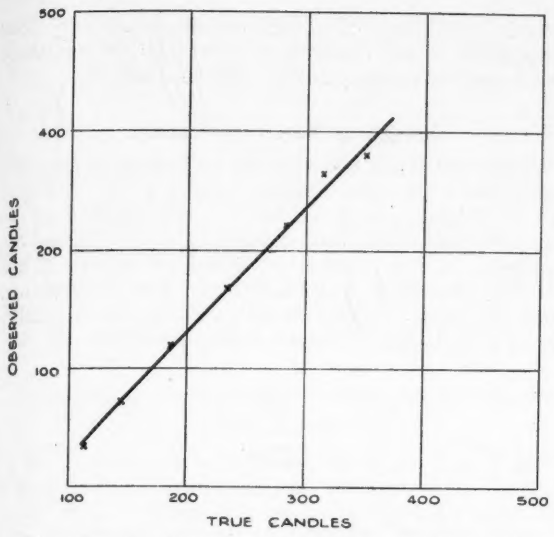

Fig. 4. Linearity of Photometric Response.

lamp on account of the difficulty of determining the actual full incandescence and nigrescence periods. It will be seen from the curves in Figs. 1 and 2 that above 90 per cent. on the heating curve and below 10 per cent. on the cooling curve, the intervals became almost indeterminable. Probably, however, the final stages of the heating and cooling, although covering a considerable period of time, can be neglected as having no practical significance.

The time interval necessary for the lamp to attain 90 per cent., or to fall to 10 per cent., of its full intensity, will be referred to as the incandescence and nigrescence periods and denoted as T_i and T_n respectively.

It will be noticed that the ratio of the above two intervals of time is sufficiently nearly constant for most practical purposes, at all events up to 10 amperes . The variations experienced above this range will be discussed later.

sent manufactured, and to cover, as evenly as possible, the limits of current rating used in practice, viz., 0—50 amperes.

In Table 1 (page 112) a complete list of the lamps tested will be found.

For lamps taking up to 10 amps., the supply volts were determined for each lamp, at which the efficiency was such as to produce the normal life; whilst the heavier current lamps were controlled on rated current, as in general practice. It will, however, be shown subsequently that moderately small changes in efficiency have an insignificant effect on the time characteristics.

Figs. 5 and 6 give the actual incandescence and nigrescence curves obtained by the methods of measurement already described. These results were obtained with supply circuits of normal resistance such as might be expected in practice.

Table 1 shows intervals of time taken for each filament to rise to 90 per cent. or cool to 10 per cent. of its maximum brightness*, from the instant of switching on or off of the supply circuit.

These intervals were selected as being representative of each

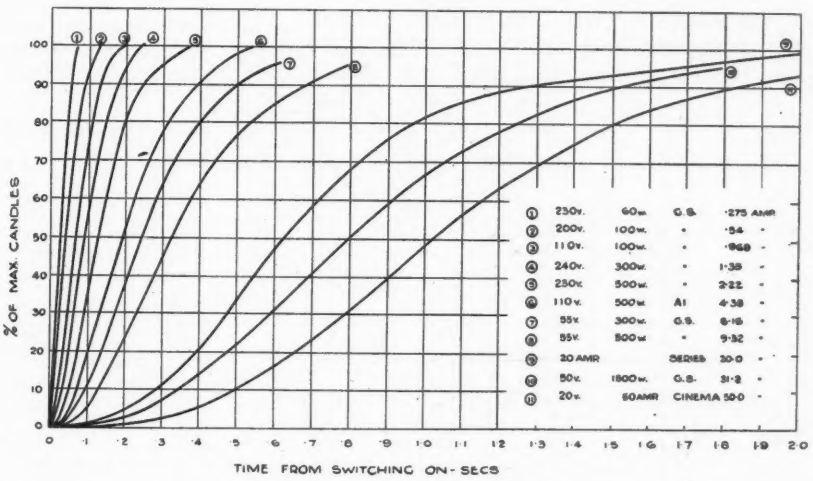

Fig. 5. Incandescence Curves.

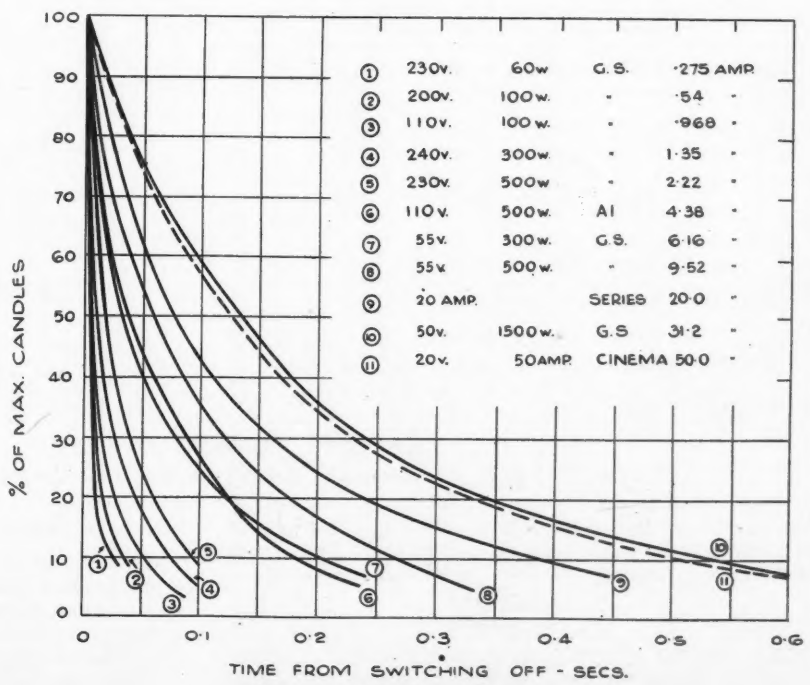

Fig. 6. Nigrescence Curves.

* This is thought to be a more useful criterion than that used by Worthing, i.e., the time to heat from 20 per cent. to 70 per cent.; for his figures indicate that the time to heat to 20 per cent. may exceed the time from 20 per cent. to 70 per cent.

Table 1.

Lamp Rating	Class	Steady Current Amps.	Time to 90% Incandescence Secs.	Time to 10% Nigrescence Secs.	Ratio of Incandescence time to Nigrescence time
230v. 60w.	General Service	0.275	0.057	0.025	2.28
200v. 100w.	ditto	0.54	0.09	0.035	2.57
110v. 100w.	ditto	0.968	0.13	0.05	2.6
6v. 6w.	Sidelight	1.0	0.17	0.065	2.62
240v. 300w.	General Service	1.35	0.185	0.07	2.65
230v. 500w.	ditto	2.22	0.245	0.092	2.66
6v. 24w.	Headlight	3.62	0.39	—	—
12v. 48w.	ditto	4.16	0.36	0.14	2.57
110v. 500w.	A1 Projector	4.38	0.4	0.18	2.22
55v. 300w.	General Service	6.16	0.51	0.2	2.55
55v. 500w.	ditto	9.52	0.68	0.26	2.60
20 amp.	C. C. series lamp	20.0	1.26	0.4	3.15
20v.20amp.	Cinema Projector	20.0	1.26	0.4	3.15
20v.30amp.	ditto	30.0	1.32	0.6	2.2
50v. 1500w.	General Service	31.2	1.5	0.53	2.83
20v.50amp.	Cinema Projector	50.0	1.8	0.51	3.54

Empirical Relation of Incandescence and Nigrescence Times and Current Rating.

If the logarithms of the incandescence and nigrescence periods are plotted against the logarithm of the current rating of the lamp, as in Fig. 7, the points are found to lie quite well on two straight lines from which the following empirical relations are found:—

$$T_i = 0.138\ I^{0.73}$$
$$T_n = 0.059\ I^{0.68}$$

where I is the steady current rating of the filament.

A few lamps give results which depart somewhat from the straight lines, probably owing to heavy end cooling or to unusually high efficiency. Very low voltage lamps are likely to have rather longer times than lamps of normal voltage for this reason.

Effect of Rapid Switching.

Where the lamp is switched on before it has had time to cool, the incandescence curve given in Fig. 5 will be followed as from the relative intensity to which the lamp had cooled when it was switched on. Similarly, if the lamp is switched off before it has had time to reach full intensity, the nigrescence curve of Fig. 6 will be followed as from the intensity which it had reached when it was switched off.

Effect of Moderate Deviations from Designed Efficiency.

Fig. 8 illustrates the effect of a decrease in efficiency of approximately 25 per cent. This involves a decrease of 8 per cent. in current and 10—12 per cent. in volts, and an increase in the incandescence and nigrescence periods of 11 per cent. and 16 per cent. respectively.

The small variations in normal running efficiency, which might be experienced in practice, may be expected therefore to have only a relatively small effect on incandescence and nigrescence periods.

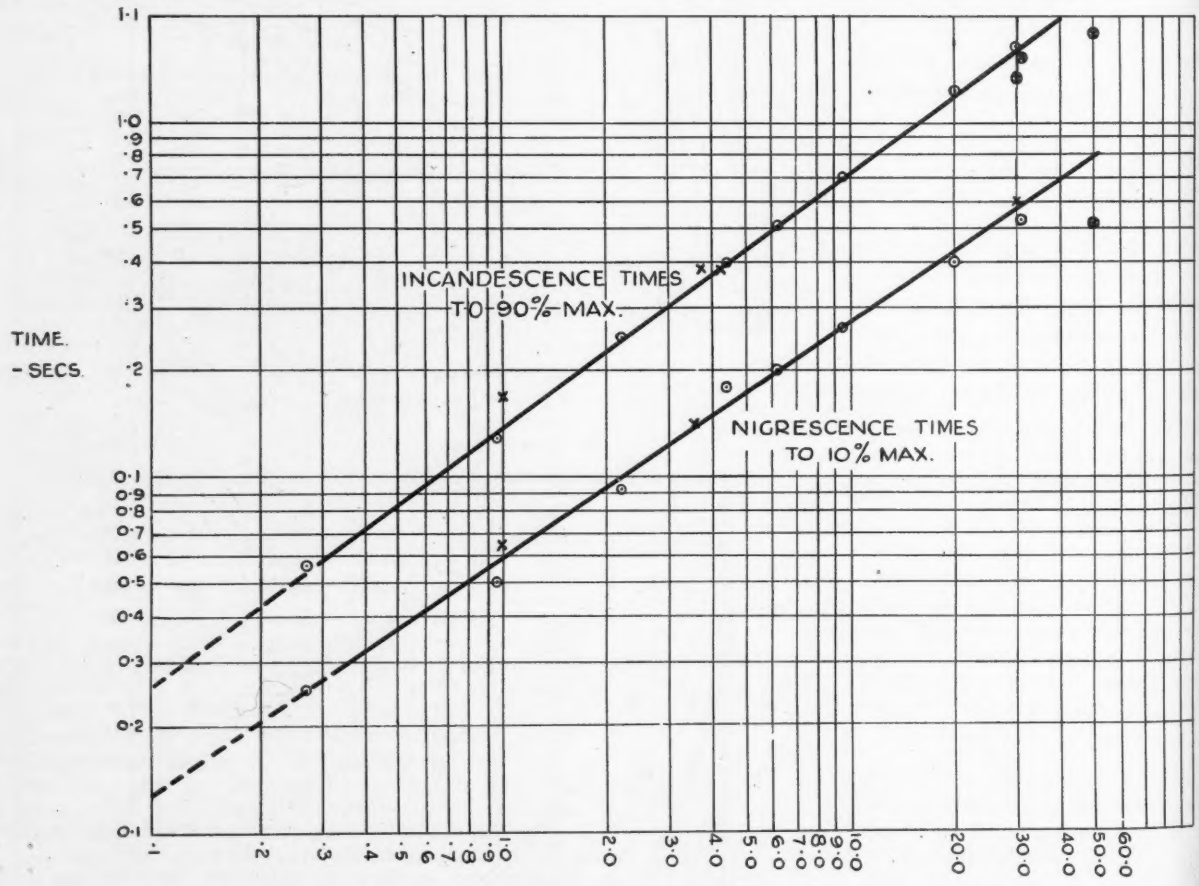

Fig. 7. Incandescence and Nigrescence Time/Current Relations.

Effect of External Resistance.

(*i.*) *Resistance Shunting of Switch.*—It will be seen from Table 1 that the ratio of the incandescence and nigrescence periods is approximately 2.6, i.e., most gas-filled tungsten filament lamps take approximately 2.6 times as long to heat as they do to cool.

When desirable, the incandescence period can be shortened and the nigrescence period increased by

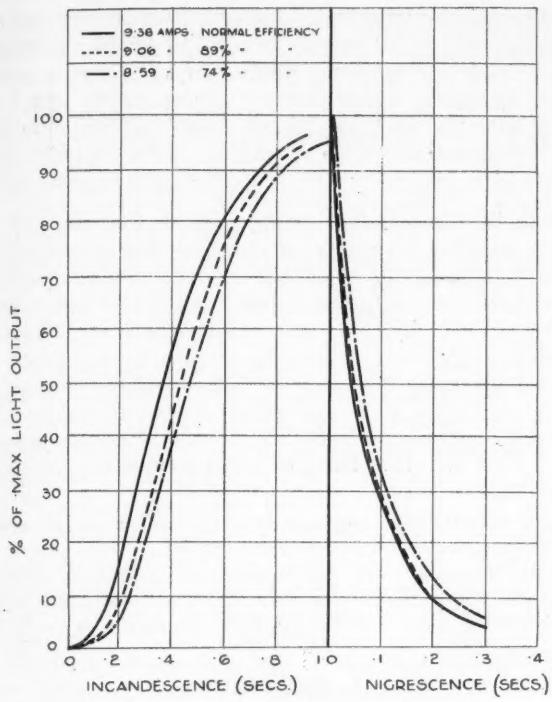

Fig. 8. Effect of Change of Efficiency.

shunting the controlling switch with a resistance. When the switch is opened, the resistance, now in series with the lamp, passes sufficient current to keep the filament warm, and so to avoid the initial warming up period. This, of course, has the additional effect of increasing the nigrescence period, because the filament is not cooled to room temperature.

In Fig. 9 is shown a set of representative curves, measured with different values of shunting resistance (R_1). The resistance in this case is expressed as a ratio of shunting resistance to lamp resistance when hot. This indicates the expected shortening of the incandescence period accompanied by a lengthening of nigrescence period. Since the current passed by the shunt is used to warm the lamp, its effect on the incandescence curve is simply to shift the curve to the left parallel to itself.

Three lamps in all were measured in this manner, and the combined results are shown in Fig. 10. The gain in incandescence and loss in nigrescence periods are here plotted again the ratio $\frac{R_1}{r}$ from which it will be seen that a shunt of 1 or $1\frac{1}{2}$ times the hot resistance of the lamp is necessary to make a material difference, and that the incandescence and nigrescence periods become equal when the shunt is 0.85 of the hot lamp resistance. It might be imagined that if the incandescence and nigrescence period were made equal, the lamp would be operating at its maximum speed as a signal lamp.

For most purposes, however, the value of the shunt for complete blackout of the filament can be taken

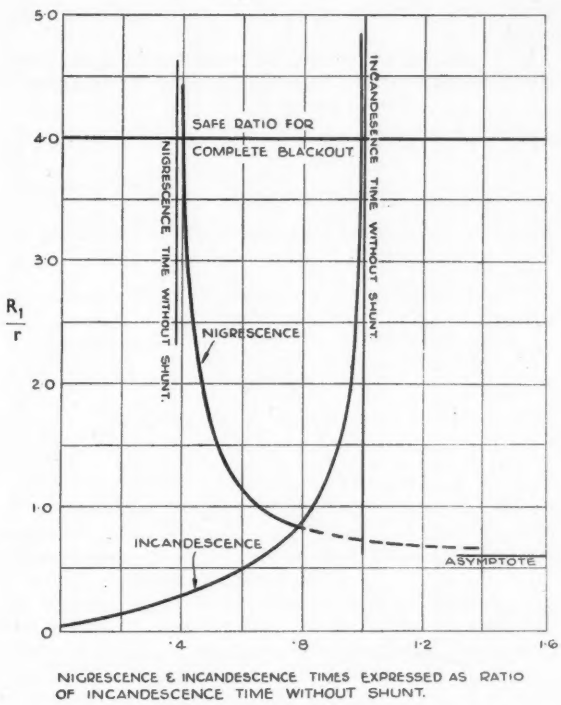

Fig. 10. Effect of Resistance Shunt across Key.

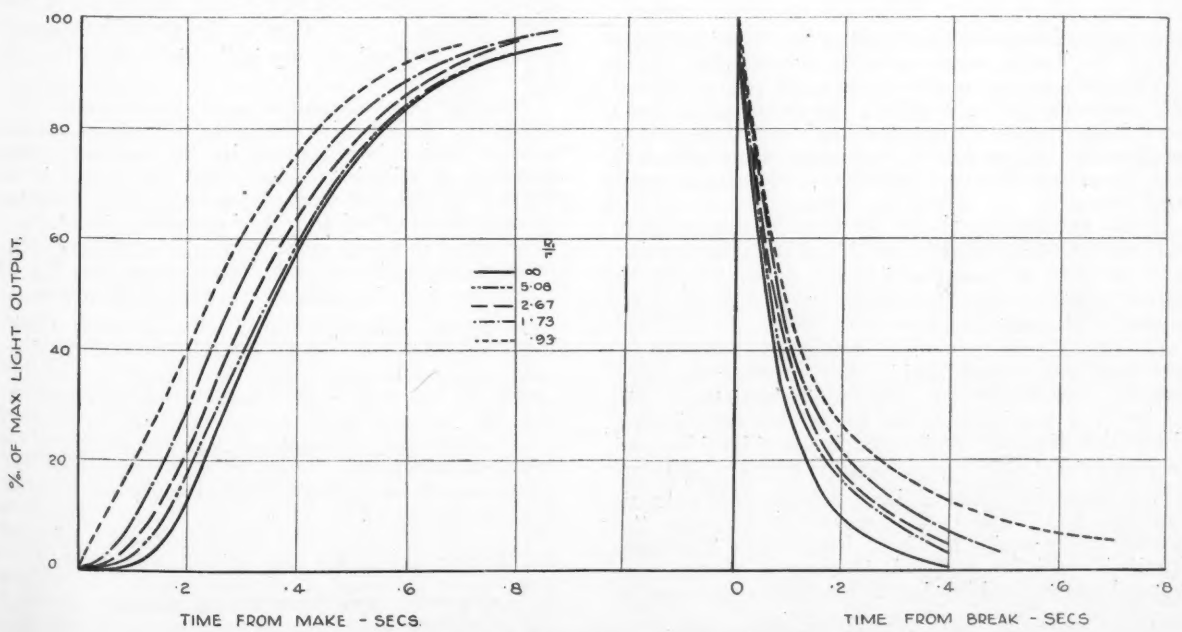

Fig. 9. Effect of Resistance Shunt across Key.

to be approximately 4 times the hot resistance.* When the value is 0.85 the lamp is well alight. Therefore, where complete blackout is essential, there can be little or no advantage in employing a shunt, as indicated by the line through the 4:1 ratio of $\frac{R_1}{r}$ on Fig. 10. In some cases, however, for instance in long distance lamp signalling, this method might be employed with advantage, for it is not then essential to obtain complete blackout owing to the limited range at low intensities.

(*ii.*) *Effect of External Series Resistance.*—Since all lighting circuits possess a certain amount of resistance, it was considered advisable to investigate the relative effect of this factor on the time characteristics of a lamp.

Series resistance naturally limits the initial current rush, and therefore greatly increases the warming-up period of the lamp. It has, of course, no effect on the nigrescence period, since the lamp cools on open circuit.

Fig. 11 shows a representative set of incandescence curves, measured by inserting known resistances in

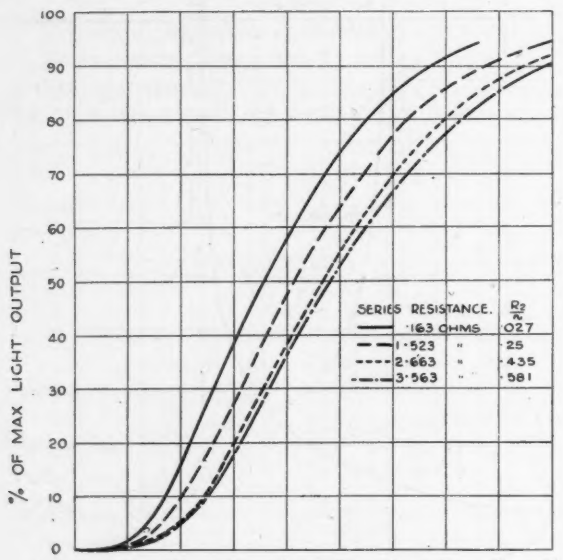

Fig. 11. Effect of Series Resistance.

the supply circuit, whilst keeping the terminal volts across the lamp constant under steady conditions. The natural circuit resistance was, of course, added to the specific values inserted. By plotting the time taken in each case against the total resistance it was possible, by extrapolation, to find an approximately true incandescence period for a circuit of zero resistance.

Fig. 12 shows the relation derived from a series of such curves, in which the ratio of total circuit resistance to that of lamp resistance when hot, $\frac{R_2}{r}$, is plotted against the percentage increase in time caused by the resistance.

A study of this curve will show that series resistance can have a considerable effect on incandescence periods. The effect of a given mains resistance will not be very marked in the lower wattage lamps, where the filament resistance is considerable, and therefore the ratio $\frac{R_2}{r}$ very small. For a 55-volt 10-ampere lamp the effect of the resistance of the circuit employed (0.17 ohms) will be seen to increase the incandescence period by about 6 per cent. The same circuit, if used for a 20-volt 50-ampere cinema projector, however, which has a filament resistance of

* Jolley, Waldram, Wilson: "The Theory and Design of Illuminating Engineering Equipment," Chapman and Hall, p. 607.

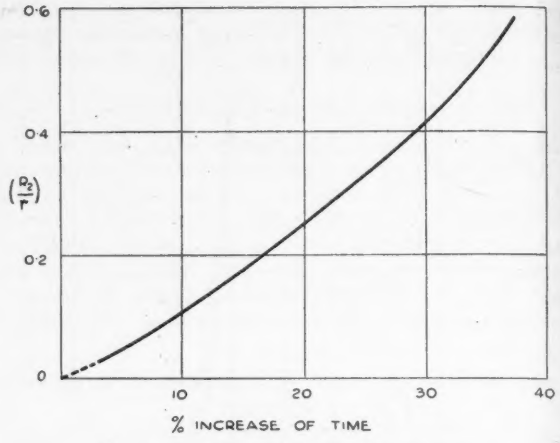

Fig. 12. Effect of Series Resistance.

approximately 0.4 ohms only, will cause a 35 per cent. increase in the incandescence period.

An increase over the theoretical time may therefore always be expected in most practical circuits, which increase will be marked where the ratio $\frac{R_2}{r}$ is large.

4. Applications.

(1) Electric Signs.

The most straightforward application of the above data is to electric signs, in the design of which the speed of nigrescence of lamps used is often very important, particularly in signs simulating rapid motion. In some types a high speed of nigrescence is desirable, and in some a lower speed. For instance, a sign intended to represent a slow, gentle movement, such as curling smoke, requires quite long incandescence and nigrescence periods if a jerky effect is to be avoided. On the other hand, "drifting" news signs, in which a series of letters is caused to drift across the face of a bank of lamps, require a very high speed of nigrescence, otherwise the letters appear to leave a trail behind them rather like a "travel ghost" on a badly adjusted cinematograph. The form of the indication given by a sign of this kind can be very easily determined. On any elevation of the sign to a convenient scale, the incandescence and nigrescence curves of the lamps can be plotted, using the scale of distance as a scale of time, where 1 ft. = $\frac{1}{v}$ sec., v being the speed of apparent movement of the letter or indication along the face of the sign.

The duration of contact is represented as a distance, and does not vary with the speed: it is the length of the sign which is energised by the contact at any moment. It will be evident that the result is unaffected by the number of lamps or their spacing, which is determined by other considerations.

The effect of speed upon the shape of the indication and the length of the "tail" can be seen from Fig. 13. In drifting signs in which a "tail" is a disadvantage,

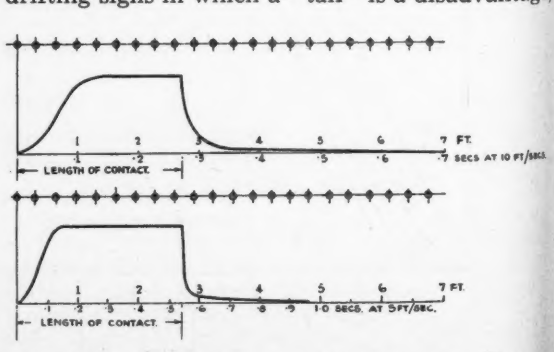

Fig. 13. Indication given by Drifting Sign.

the permissible tail length is probably determined by the height of the letter, and, consequently, for a given lamp current the maximum speed of the sign is a function of the height of the letter. Suppose, for instance, that a "tail" not longer than m times the letter height is desirable, then the maximum speed of the sign is $V_{max} = \frac{mH}{Tn.}$.

The constant m would have to be fixed by experience, but would probably be about 0.2. There is a further obvious limit to the speed of the sign, however, that the contact duration should be not less than the incandescence period.

The latest drifting signs make use of small electric discharge tubes instead of filament lamps, so that the period of incandescence and nigrescence is practically *nil*, and a very sharp and clear indication can be given at any speed.

(II.) Signals and Beacons.

(*a*) *Morse Signalling.*—Communication by light signal, using the International Morse Code or a simple arrangement of flashes, is used for a variety of purposes. These vary from the transmission of fairly long messages to the broadcasting of one or two letters or numerals which convey an order or information according to a recognised code. The intensity distribution of the signal may vary from a very narrow angle beam to a signal extending over the complete hemisphere, depending on the service which it is required to give.

The nature of the message determines the signalling speed. Long communications can be sent by light signal by very skilled signallers, at speeds up to 15 words per minute or more. The usual speed for ordinary skilled signallers is about 8 words per minute. Short messages, orders, etc., consisting of a few letters and intended to be read by unskilled signallers, are sent slowly at about 5 words per minute or less, while identification signs, beacons, etc., may be sent very slowly.

The intensity distribution of the beam of light determines the characteristics of the lamp. The greater the solid angle of the beam, the more flux will be required for a given range, and the greater will be the power of the lamp necessary. The smaller the solid angle of the beam, the smaller must be the filament of the lamp, and consequently the less the filament voltage, and for a given flux output, the greater the current. Small narrow beam long range signal projectors suitable for high speed signalling cannot, therefore, be operated by keying the lamp circuit, and, in effect, for a given beam divergence the signalling speed sets a limit on the range. Wide angle signal projectors can usually be designed for larger filaments, and in consequence it is possible to use high voltage lamps of low current or with several low current filaments in parallel.

Morse Code.—In the Morse alphabet, as is well known, letters and numerals are composed of combinations of signals of long and short duration known as dots and dashes. The letters of most frequent occurrence are given the shortest signals. The length of the dot is taken as one unit: the length of a dash is three units. The space between elements is one unit, between letters three units, and between words six units. The period during which a signal element is being transmitted or received, or during which the signalling circuit is energised, is known to telegraph engineers as the "marking" period; the corresponding period during which the space between signal elements, letters, or words is being transmitted is the "spacing" period. These terms will be used in what follows, referring either to the electrical circuit or to the light signal sent or received.

The length of the various letters and numerals in the code is given in Table 2.

Table 2.
Lengths of Morse Characters.

Letter	Length in units	Letter	Length in units
E ·	1	C — · — ·	11
		O — — —	
I · ·	3	P · — — ·	
T —		X — · · —	
		Z — — · ·	
A · —	5	4 · · · · —	
N — ·		6 — · · · ·	
S · · ·			
D — · ·	7	J · — — —	13
H · · · ·		Q — — · —	
M — —		Y — · — —	
R · — ·		3 · · · — —	
U · · —		7 — — · · ·	
B — · · ·	9	2 · · — — —	15
F · · — ·		8 — — — · ·	
G — — ·			
K — · —		1 · — — — —	17
L · — · ·		9 — — — — ·	
V · · · —			
W · — —		0 — — — — —	19
5 · · · · ·			

If a message is sent at the rate of n words per minute (a word being reckoned as five letters), then in one minute it will be necessary to send

n words + n word spaces or

$5n$ letters + $4n$ letter spaces + n word spaces.

For messages sent in clear, the average length of a letter is 5.6 dots, so that in one minute the number of dots sent is $5 \times 5.6n + 4 \times 3n + 6n = 46n$ dots.

and the length of one dot is $\frac{1.3}{n}$ sec.

For code messages, in which there is an equal chance of any letter or numeral being sent, the average length of one letter is 9.3 units, and the number of dots per minute is then $64.5n$, and the length of one dot is $\frac{0.93}{n}$ sec.

Relation between lamp current and signalling speed.—There is a possibility that signals are not read in the same way at long and short ranges. At short range the determining factor is the observation of the spaces—i.e., the lamp must appear to go out, or at least to diminish markedly in intensity. At extreme range the criterion is observation of the "marks," i.e., the lamp must be able to reach its full intensity. As the range which a given lamp is read is decreased, so the possible speed is increased until at very short ranges, such as sometimes occur in military lamps, the signal is unreadable because the spaces are not properly formed. The apparent length of the space may be further reduced at very short ranges by glare and after-images.

In either case the determining factor is the incandescence curve of the lamp. The nigrescence time is always shorter than the incandescence time, and the intensity drops very rapidly indeed immediately after switching off. Therefore, the incandescence period should be not greater than the length of one unit. At medium range higher speeds can be obtained, for a clear space will be seen even if the lamp never goes completely out. At short ranges, expert signallers can read a signal in which the intensity in the spaces is reduced only by a small

amount, and the speed can then be considerably increased. But for really clear signals the above criterion must obviously be taken as a basis. If, therefore, the incandescence period is taken as equal to the length of a dot, the relation between the maximum signalling speed and the maximum lamp current is shown in Fig. 14 for messages in clear and

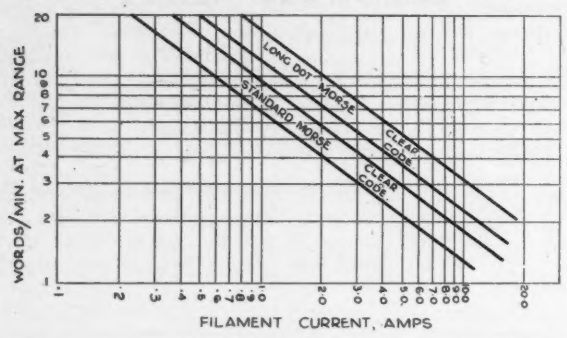

Fig. 14. Theoretical Signalling Speed/Current Relation.

for messages in code respectively. An experimental test of these relationships is given later with a discussion of some factors which modify these conclusions and allow an increased speed.

Relation between Keying and Resultant Signal.—The result of the long incandescence and nigrescence period of the lamp is that the signal sent by the lamp is not of the same shape as the signal keyed, and the keying may have to be modified to suit the characteristics of the lamp.

A beacon has generally to be identified at extreme range. The received signal is, therefore, defined by the time during which the lamp is at full intensity. Suppose that the desired signal consists of a series of flashes, the marking and spacing periods of the received signal being equal. The actual shape of the signal at the highest speed of which the lamp is capable will be as shown in Fig. 15, with the corresponding shape of the key signal.

The least length of the space will be $T_n + T_i$, where T_n and T_i are the nigrescence and incandescence periods respectively, or if $T_i = KT_n$ the least length of space is $T_n (1 + K)$. The length of the mark period will be the same. But the shape of the

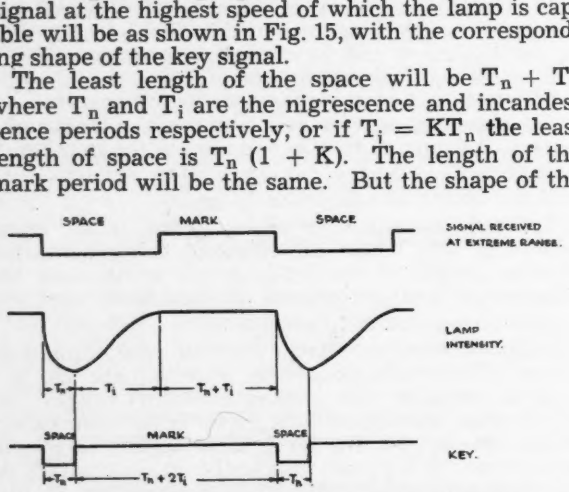

Fig. 15. Effect of Keying on Resultant Signal.

key signal will be quite different—the marking period will be $T_n + T_i$ and the spacing period will be T_n, or $T_n (1 + 2K)$ and T_n respectively. If K = 2.6 the marking and spacing periods for the key will be in the ratio of 6.2:1. For filaments taking 5 and 10 amps. the times for maximum speed are as given in Table 3.

Table 3.

Filament current. amps.	T_n sec.	T_i sec.	Length of received space ($T_n + T_i$) sec.	Key marking period sec.	Key spacing period sec.
5	.17	.44	.61	1.05	.17
10	.27	.72	.99	1.61	.27

In effect, the contact is made early by an interval equal to the incandescence time.

If, for nearer ranges, the limit of the flash were taken as the period during which the lamp is over 50 per cent. full intensity, then the time to 50 per cent. full intensity will be very nearly $\frac{T_i}{2}$, while T_n will be very little altered. The shortest marking time for the received signal would then become $T_n + \frac{T_i}{2}$ or $T_n (1 + \frac{K}{2})$, and the marking and spacing periods for the key would be $(T_n + T_i)$ and T_n, or $T_n (1 + K)$ and T_n, so that the ratio is now $(1 + K)$; or for K = 2.6, the ratio is 3.6:1.

(*b*) *Signalling Test.*—The curves of Fig. 14 give the maximum speed under the worst possible conditions, i.e., when the range is so great that the light can only just be discerned. This is a condition in which reading is in any event very difficult, and for signalling lamps it is hardly ever actually used. In practice either the power of the lamp is increased or the range decreased so that the signal is more easily readable. The conditions laid down above, namely that the lamp can just be seen at full intensity, and that the shortest dot period shall not be less than the incandescence period, now no longer hold, and in practice higher speeds can therefore be obtained.

A further variable exists in the way in which the lamp is keyed. If the keyed signal is made in accordance with the Morse standard, the marking and spacing intervals being of the same length, then since the incandescence period is longer than the nigrescence period the lamp will tend to "clip the dots." If, however, the key is operated so as to close the contacts early, as already pointed out, this effect can be compensated. A signaller working with a lamp signal is trained to avoid "clipping the dots" and actually does work the key in this way. It is usual when keying a lamp circuit to hold the key differently from a telegraph key; in the latter the thumb and second finger rest on the shield and the index finger on the top of the knob, the hand being then relatively stiff and able to send at high speed. For lamp signalling, however, the first and second finger rest fully extended on the knob; the signaller moves the whole of his hand in sending, and the spring of the extended fingers lengthens the period of contact almost automatically. When the key is so held it is more difficult to send too fast or to make short dots.

In order to determine the actual possible speeds a test was made, with the help of the War Department, of the possible speeds of signalling with lamps of various currents. Trials were made both in a miniature range in the laboratory and over a longer range of about a quarter of a mile outdoors, both being in the dark. (It was considered undesirable to introduce the further variables associated with day signalling.) The maximum readable speed was determined for each of four lamps for three different intensities and for three different methods of keying. The intensity was first adjusted until the lamp was judged to be at extreme range, i.e., in the opinion of two expert signallers it could just be read on very slow Morse signals.

The maximum readable speed was determined for this condition and also for intensities of five and ten times that for extreme range. The three methods of keying were: automatic standard Morse, automatic "long dot" Morse, and hand sending. The shape of the impressed signal and of the resultant lamp signal is shown in Fig. 16 for the first two types. In the "long dot" Morse, the "make" period is timed to commence early by an interval proportional to the incandescence period, the break or space period being proportional to the nigrescence period as described above. Thus, the "long dot" Morse gives a perfect signal at extreme range, at a speed at which the standard Morse is only just readable. At long

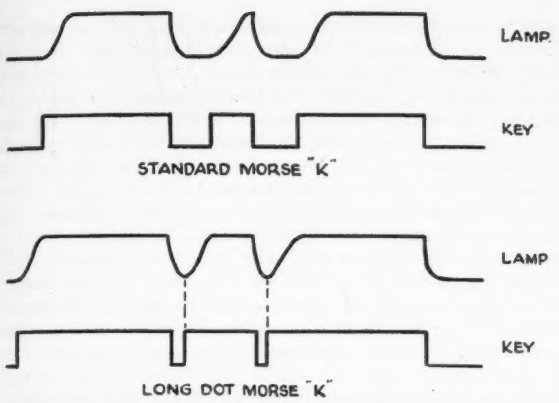

Fig. 16. Standard and "Long Dot" Morse Signalling.

ranges it should, therefore, be more readable, but at very short ranges it is probably less readable, for the spaces are too short.

METHOD.

The lamps were used in a lantern projector, which was made to project a small patch of light about 2 in. square. A steel ball-bearing, ¼ in. in diameter, was placed in this patch and formed a very small image of the projection lens, making a good representation of a distant signal lamp. The intensity could be adjusted by changing the size of the ball and by placing the lamp out of focus in the lamp house. A sector wheel was also arranged in the beam, and when setting up the apparatus for extreme range a sector of 10 per cent. transmission was used. By changing to a sector of 50 per cent. transmission or by stopping the sector, the intensity could be made five and ten times that for extreme range.

The lamps were keyed by a vacuum switch, as previously described, the operating coil of which was controlled either by a standard lamp sending key or by the automatic sender. The latter consisted of a rotating horizontal brass disc having a finger in contact with its upper surface, on which was placed a paper disc having the required characters perforated in it. Standard and "long dot" characters were arranged on different radii and could be selected by changing the position of the finger.

For the outdoor tests the same apparatus was used, except that two plane mirrors were used instead of the ball. The letters sent were of the mean length for code messages, and were selected with a view to demonstrating the effects described.

RESULTS.

The results are given in Table 4.

The following conclusions are to be drawn:

(1) The result for extreme range were nearly all faster than the theoretical speeds, by a factor varying from 1 to 2 (neglecting the very doubtful outdoor test on the 10-amp. lamp). This was probably due to difficulty in judging the initial conditions for "extreme range."

It will be realised that the speeds given are maxima, i.e., they represent a speed at which a trained signaller begins to find the signal uncertain. An inexpert signaller could not read at these speeds. They do not represent the fastest for certain communication; for this a working speed of approximately half the values given might be taken. The net result is that the theoretical values can probably be taken as a guide to the maximum current for a given safe working speed.

(2) The "long dot" Morse was definitely faster than the standard Morse, and gave closely similar results to the hand sending. In considering the latter results it should be borne in mind that the signallers were accustomed to use a speed of eight words per minute and found a little difficulty in sending accurately at speeds much faster or slower than this. They considered fifteen words per minutes as the limiting speed, apart from questions of lamp speed.

(3) At intensities greater than that for extreme range, the speed was increased, and in some cases doubled, though the increase was less with "long dot" than with the standard Morse.

The results of Table 4, therefore, though they do not agree very closely with those of Fig. 14, are useful in giving an indication of the order of variation from the values of Fig. 14 under different conditions in practice.

5. Conclusions.

Investigations of time constants of lamps could doubtless be carried into much more detail. It is felt, however, that the present experimental data may suffice for the majority of practical cases, and it is hoped that they may at least help a designer to an approximate result which can be adjusted afterwards by experiment.

The Laboratories desire to acknowledge their indebtedness to the R.E. Board and to Lance-Corporals

Table 4.

Experimental Maximum Signalling Speeds (words/minute).

Lamp Rating and Type	Current Amperes		Extreme Range			5 times intensity for extreme range.			10 times intensity for extreme range.		
			Std. auto.	Long dot auto.	Hand.	Std. auto.	Long dot auto.	Hand.	Std. auto.	Long dot auto.	Hand.
230v. 250w. A1	1.1	Indoor	7½	12	13	13	—	15 (limit)	13	—	—
		Outdoor	8½	—	11	—	—	—	—	—	—
110v. 250w. B	2.25	Indoor	6½	10	10	10	—	12½	12½	12	13
		Outdoor	8	9	10	8	9	9—10	8	—	7½—8
220v. 1,000w. B	4.5	Indoor	4½	7	6½	8½	—	10	9½	—	11
		Outdoor	—	not	tested		—	—	—	—	—
12v. 120w. Loco. Headlight	10	Indoor	1½	2.4	2.3	2.2	5½	5½	4	5½	5¾
		Outdoor	2¼	5¼	7	—	—	—	—	—	—
			uncertain								

Garner and Grieve of the Royal Corps of Signals for their assistance in the signalling test.

References.

Author	Periodical	Reference	Remarks
Lloyd	El. Rev.(Amer.)	1911 p. 94	Transient characteristics. Effect of wave-form.
	Electrot. Zeitsch.	1913 (Feb. 27th)	Cyclic variations.
Makower	Electrician	1914 (V. 73) p. 837	Starting currents of gas-filled lamps.
Langmuir	Gen. Elec. Rev.	1914 p. 294	Cyclic candle power variations.
Markle	El. World	1917 (V. 70) p. 579	Flicker of lamps.
Simons	Electrot. Zeitsch.	1917 (V. 38) pp. 453, 465, 475.	Transient characteristics.
Berry	El. World	1918 (V. 71) p. 459	Initial currents in incandescent lamps.
Forsythe	Phys. Rev.	1920 (V. 16) p. 62	Speeds in signalling with incandescent lamps.
„	N.E.L.A. Abstracts	V. 1, No. 4 p. 127	
Worthing	Jour. Frank. Inst.	1920 (V. 189) p. 788 1921 (V. 191) p. 115	Flashing speeds of incandescent lamps.
Blandy	Ill. Engineer	1922 p. 42	Flashing types of beacons.
	Jour. Inst. Elec. Eng.	1926 (V. 64) pp. 1090-1092	Cyclic characteristics.
Kurth	Arch. f. Electrot.	1929 (V. 23) pp. 124-148	Cyclic characteristics.

Jolley, Waldram & Wilson: "The Theory and Design of Illuminating Engineering Equipment," (Chapman & Hall) 1930, pp. 94, 406, 605.

DISCUSSION.

The CHAIRMAN (Mr. A. Cunnington) remarked that the paper would make a valuable addition to the records of the Society, and commented on the excellent demonstrations that had been given in connection with it.

Papers before the Society usually contained a good deal of descriptive matter, but did not very often give results of research of this character. The President had more than once expressed a desire that there should be more papers of this kind, and therefore it was particularly unfortunate that he was not present to hear this paper and to see one of his desires fulfilled.

There was also a tendency to put the results of research into print without very much details as to how these results had been arrived at. It was a rare thing for the conjurer to give away his tricks, and they would all feel grateful to the "conjurer"—Mr. Waldram—for showing how the results had been achieved. His demonstration had been an excellent accompaniment to the presentation of the paper by Mr. Sandford. The members were not only indebted to the authors for this paper, but also to the General Electric Co., whose Research Laboratories at Wembley had been the seat of this work, and it was, of course, with the permission of the General Electric Co. that this paper had been presented to the Society. In the circumstances, therefore, as Mr. Paterson, the Director of the G.E.C. Research Laboratories, was present, it would be appropriate if he would open the discussion on the paper.

Mr. C. C. PATERSON said he understood that Col. Silvester Evans would open the discussion, and he was unprepared to do justice to the very useful paper which the authors had presented. He thought this was a subject which particularly concerned the Services. Listening to the paper and watching the very interesting demonstrations, he was reminded of the days of 25-cycle electricity supply, when some people were much bothered with flicker. It was then quite a question to know how to excuse the introduction of the thin filament gas-filled lamp when it first came in, on account of the rapid flicker effect which it exhibited. Could the authors say, from their experiments, the minimum amount of flicker in the light, which the eye could observe? He knew, of course, that the authors had been studying the other aspect of the problem and had demonstrated how much flicker was needed to see a signal properly. It would be interesting to know, however, the minimum amount of flicker which the eye could observe; also whether or no expert signallers found, when they were experiencing difficulty in interpreting a signal, that they got it best by direct vision—or by peripheral vision?

Col. C. H. SILVESTER EVANS congratulated the authors, and especially the "conjurer," because all his tricks worked! The demonstrations were excellent. The data in the paper was such that he wished he could have had them about two years ago, because they would then have saved him many months of bitter trial and error. At the same time he would have liked the authors to have given more data concerning the low voltage high wattage lamp, and in this connection he was thinking of the case of a 12-volt 200 or 300-watt lamp which he had had considerable trouble in using for certain signalling purposes. Such lamps would fall into the category of those mentioned by the authors which would depart from the straight line from which they deduce their formula. The low voltage lamp was particularly important in all portable signalling or beacon apparatus, which necessitated limited battery power to the extent that it was not possible to carry about large secondary cells. There was one point concerning this which he was rather concerned about, and that was what was going to happen to portable apparatus when the battery was slightly down and a considerable amount of series resistance was introduced by bad connections. The authors had mentioned that they had not considered the daylight signalling problem, but he had been impressed when watching the authors' demonstrations by the fact that when the lights in the lecture hall were out, it was much easier to read the neon lamp than the other lamp. This led him to make the suggestion that possibly for daylight signalling the introduction of a *slight* amount of colour might be useful. When using a dioptric lens with, say, a 300-watt 12-volt lamp, it was difficult in sunlight to read signals, and his experience had rather suggested that "cut-off" was more important than incandescence. This, of course, was very different in many aspects from the dark signalling which had been demonstrated that evening, and the battery power for the class of work that had been demonstrated was relatively high.

Col. J. P. G. WORLLEDGE said he would like to congratulate the authors on their excellent paper. He remarked that the question of colour in daylight signalling had been gone into during the War and various colours were tried in order to be able to distinguish a signal from the flashes from bursting shells. It was found, however, that the colour cut down the light so considerably that the results were not very satisfactory. One point upon which he would like further information was with regard to the series resistance. He did not understand why a series resistance should affect the rate of growth of the current in any way, unless it was highly inductive.

Mr. G. H. WILSON said it was very refreshing to have results of experimental work like this to add, so to speak, to the data sheets of the Transactions of

the Society which could be referred to at a later date for real information on technical matters. One of the most surprising things to the ordinary observer was that the incandescence time should be 2½ times the nigrescence time, because, in observing these lamps, the impression was that they took a long time to cool down and did not seem to be taking so long to come up. Could the authors say whether that was due to the fact that one did not know when the circuit was made, and, in combination with that, one did not see the early part of the incandescence curve? The experiments had been extremely interesting, but he imagined that it was really necessary to observe for some minutes in order to be correctly adapted to the brightness in order to get true effects. That might be the reason why those present were not all agreed as to when the dots were visible and when they were not. Further, sitting in a comfortable room and observing was rather different from being out on a cold and windy night when one's eyes were watering, and trying to see a small point source of light in the distance. With regard to an apparent wavering effect of the light at high speed, he presumed that was due to the lamp not being up to full intensity on the dot, but quite apart from the difficulty of distinguishing dots as dots, he had found this wavering effect rather disturbing, and it would surely make the reading of a message of some length quite difficult.

Could the authors give a reason for switching a lamp in order to obtain the flashing effect in a lighthouse? It seemed to him that in order to obtain the maximum efficiency there should be some sort of optical system which could collect most of the flux and concentrate it into a narrow beam and which could then be rotated. It was true that switching was the simpler process, and he would like the authors' view as to whether or not this method was adopted because of its simplicity in preference to the rotation of an optical system.

Mr. G. T. WINCH, the designer of the photo-electric photometer, mentioned in the paper, said that there was nothing particularly novel about the circuit which was now widely used, and he therefore thought it unnecessary to describe it.

The component parts of the photometer, comprising a photo-electric cell in a D.C. valve bridge circuit, were housed in one unit which was useful for various precision photometric purposes. It was used in the laboratory in conjunction with a monochromator for making spectro-photometric measurements and in conjunction with a photometric integrator could be used to measure luminous flux.

An unusual construction was used to render the circuit stable and capable of high precision, but it could hardly be briefly described.

Mr. J. S. Dow remarked that the authors rather seemed to imply that the limits to this work were set by physical conditions. One was inclined to suggest that it was necessary also to take into consideration the physiological side, and especially whether the eye was an expert one or not. Furthermore, assuming one was viewing a flickering light at a great distance or under atmospheric conditions which involved observation of a very faint light, would it not be possible that the limit might be materially affected by physiological considerations, such as the part of the retina on which the image was received, the condition of the eye-lens, etc.? Again, there was the case of "following brightness," such as was experienced with certain forms of signs. Was it the fact that the presence of "tails" was determined entirely by the behaviour of the lamp-filaments. In some such cases it seemed conceivable that the impression of a tail might be due to the behaviour of the eye, especially if the distance was considerable. He seemed to remember that in some experiments on after-images it had been found that with moving faint lights, a second image was seen following up some distance behind. Might not something of that kind occur when dealing with moving lights?

The CHAIRMAN asked whether this research was likely to throw any light on the question of flicker, which occurred with the use of low frequency current for lighting purposes. People had occasionally to work under a 25-cycle supply for lighting, but personally he did not regard a low frequency supply as satisfactory. The point was whether there was any means for overcoming this difficulty by making an alteration of the circuit, or, alternatively, what was the minimum frequency that would avoid eye-strain. From some rough trials he had found that flicker in the case of an ordinary 60-watt lamp on a 25-cycle circuit was not easily detectable some distance away from the lamp, but as one got nearer to the lamp the flicker increased very rapidly. At a distance of 12 ft. in an ordinary dark room, flicker was practically invisible, but working at a desk near such a lamp was very unpleasant indeed, and with the lamp anywhere near the eye it was practically unbearable.

Mr. J. M. WALDRAM, replying to the discussion, said in reply to Mr. Paterson that the authors had not done any work on flicker of lamps on 25-cycle supply by the method described in the paper. Undoubtedly, the effect of this flicker depended very much on the conditions of viewing. He recalled some experiments a few years ago in which an office was lighted with various lamps run off a 25-cycle supply, and those who carried out the tests worked there for some time and recorded their impressions. The flicker was more noticeable with the peripheral than with focal vision. Very often the flicker was not seen at all if the lamp was looked at directly, but it was noticeable when the observer moved about. The amount of flicker altered with the current of the lamp, and with its efficiency. He had no definite information as to the minimum flicker that was observable by the eye, but in the experiment referred to it was found that a h.v. 60-watt gasfilled lamp underrun to 3.8 lumens/watt or a 100-watt lamp underrun at 6.6 lumens/watt produced no noticeable flicker on a 25-cycle supply.

Mr. WALDRAM said that he believed that the 12-volt 200-watt lamp mentioned by Colonel Evans had a number of filaments in parallel, and it would be useful to know the current of the filament.

Colonel EVANS said it was about twenty-five watts per filament; 1 and 2½ amps.

Mr. WALDRAM, continuing, suggested that the answer to Colonel Evans's question would be found in the data given in the paper. In the case of a filament such as that in a headlight lamp working at low voltage with considerable end-cooling, it was not possible to predict the performance of the lamp very precisely, but from the points plotted on the curves of Fig. 7 it would be seen that, although there were certain anomalies, they were not very serious.

The series resistance effect in a signalling circuit became more important as the total lamp current increased. In the case of the signalling lamp which had been demonstrated, there was a dry battery and the circuit was arranged with a small resistance deliberately inserted when the battery was fresh to protect the lamp, which was cut-out as the battery ran down. The lamp employed was of low current and had a sufficiently short incandescence and nigrescence period for the effect of the resistance to be negligible.

The authors had had no experience of daylight signalling. They had approached the problem from the point of view of the lamp, and they had assumed that as the speed of signalling was increased, a point was approached at which the lamp could only just

reach the maximum intensity during the period of one dot, and that speed must approximate very closely to the limit of readable signals either by day or by night. Close to the lamp it was possible to read at faster speeds, and the order of variation which occurred was seen in Table 4, which had been compiled from practical signalling tests. Whether the results would be the same in daylight, and whether the effect of range would be the same, he did not know; but he believed that results by day and night would be related. He thought that the difficulties introduced into the experiment by the nature of the background, etc., would be so considerable as to mask any useful results from a daylight test.

He agreed with Colonel Worlledge that some of the colour filters which had been used for daylight signalling were very dense, and would obviously greatly decrease the range. Mr. Waldram said that the authors were very indebted to Colonel Worlledge for his help in obtaining the services of expert signallers, who had assisted in carrying out the signalling tests. Colonel Worlledge had asked why the series resistance prevented the growth of current. The effect was due to the temperature characteristic of the filament. The filament of a tungsten filament lamp had a much greater resistance when hot than when cold. When a cold lamp was switched on there was an initial current rush which theoretically was about fifteen times the normal current. This current rush was important in quickly heating the filament through the lower part of its temperature range. As the filament heated up, its resistance increased, and a steady current was gradually reached. The introduction of the series resistance limited the initial current rush, and therefore retarded the initial heating up of the filament. A series inductance would have much the same effect.

The point mentioned by Mr. Wilson that the lamp always seemed to take longer to go out than to light up had also been noticed during these experiments, and the explanation suggested by Mr. Wilson was no doubt correct. One could not tell when the lamp was switched on, and it seemed to take a very long time to extinguish. But in signalling only the maximum brightness of the lamp was important; no signal could be produced by the "tail" of the nigrescence curve The apparent wavering of the signal light at high speed was due to the fact that the lamp had not reached full brilliancy in an initial dot, but it did so in the dash. Whether that was an ill-effect at normal signalling speed he doubted, because it probably would not take place at that speed. He believed that the reason for switching in some lighthouses instead of using a rotating system—which he agreed was very much more efficient—was partly for reasons of simplicity and also because it was not possible to get the same characters in the revolving system as could be obtained with a flashing lamp. In the case of the North Foreland light, which had been reproduced in the experiments, there were five flashes every twenty seconds. It might be possible to do this with a rotating system, but it would involve the waste of a tremendous amount of light, and greatly complicate the optical design.

In reply to Mr. Dow, the authors agreed there might be limits set by the eye in reading signalling lamps. The signallers who helped in these experiments considered that fifteen words per minute was the limiting speed with any lamp. Mr. Waldram had heard of men who could read at thirty words per minute, but had been unable to confirm the figure. Certainly the action of the eye in high-speed signalling must play a very large part, and for that reason the authors had carried out a signalling test as well as a theoretical test on the lamp. Dealing with the other point mentioned by Mr. Dow, viz., the "following" brightness in the case of certain signs, Mr. Waldram doubted whether it was entirely due to the eye. He was inclined to think that the tail was due almost entirely to the nigrescence of the lamp. In Trafalgar Square there were two signs on Grand Buildings, one of which ran at about three times the speed of the other, and the difference in the "tail" was most noticeable. Again, in Piccadilly-circus, at Shaftesbury-avenue, there was a sign using discharge lamps with which there was no perceptible tail, and the difference in clearness between that and the other signs near by was pronounced. Therefore, although there might be effects due to the eye, he believed that the effects due to the lamps were greater.

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National Illumination Committee of Great Britain

(Affiliated to the International Commission on Illumination)

Annual Report for the Year 1934

Presented at the Annual Special Meeting of the Committee on Thursday, February 14th, 1935

THE Committee has to report the loss of two valued members during the past year. Mr. A. P. Trotter, representing the Illuminating Engineering Society, and Mr. D. R. Wilson, representing the Home Office, have both found it necessary to tender their resignations, which were accepted with great regret. Mr. Trotter has been associated with the Committee since its formation, and was particularly active in its behalf in the early days. Mr. Wilson joined the Committee at its reorganisation in 1927. His association with the Industrial Health Research Board and the Factory Department at the Home Office made him an extremely valuable member, whose interest it is still hoped to retain now that he has been appointed Chief Inspector of Factories. The vacancies in the Committee have been filled by the appointment of Mr. A. W. Beuttell and Mr. E. W. Murray.

The past year has been an extremely active one, as is usual in the year preceding a plenary meeting of the International Commission on Illumination. All the sub-committees have been busy and much useful work has been done to ensure that Great Britain's contribution to the meeting will be of the same high standard as in the past. It is hoped that the efforts of the sub-committees to that end will be supplemented by the presence of a large British delegation to the meeting, which, from the range and character of the subjects under discussion, promises to be one of the most important in the history of the Commission.

It has now been decided that the plenary meeting is to be held in Germany, in July next. The technical sessions will be held, partly in Berlin from July 2 to July 5, and partly in Karlsruhe from the 8th to the 10th of that month. It is interesting to recall that the first meeting of the International Commission on Illumination took place in Berlin in 1913 when seven countries participated. Now the Commission is assisted in its international work by the co-operation of the National Committees of fifteen countries, all of which, it is expected, will be represented.

The 1935 meeting is to be devoted mainly to the discussion of the reports on the various subjects which are being studied by the Commission. There are in all twenty-five of these, and in connection with four of them the British Committee has acted in a secretariat capacity on behalf of the Central Bureau of the Commission. Reports on these four subjects by sub-committees of the National Committee have been prepared or are nearing completion. The subjects of these reports are: (1) Glare—its determination in street lighting; (2) Aviation lighting (ground lighting); (3) Traffic control signs; (4) Lighting in mines.

Sub-Committees of the National Committee have also co-operated with the various countries which have assumed responsibility for the preparation of reports on other subjects, information having been requested and supplied in connection with practically every aspect of the Commission's activities.

In the case of those subjects which are associated with the preparation of a British Standard Specification, the appropriate sub-committees of the British Standards Institution have continued to act on behalf of the National Committee, and the following specifications have been prepared during the past year:—

Vitreous-Enamelled Steel Reflectors for Electric Lighting.

Neck and Flange Dimensions of Illumination Glassware and Carriers.

Translucent Diffusing Glassware Fittings.

Internally Illuminated Yellow Diffusing Globes for Traffic Control Signals.

Land Aerodrome and Airway Lighting.

Colours of Signal Glasses for Railway Purposes.

Bullseye Lenses for Railway Purposes.

Artificial Daylight Fittings.

Portable Photometers (a) Visual, (b) Photoelectric.

An important event during the past year has been the appointment by the Minister of Transport of a departmental committee to advise on street lighting. In response to an invitation, the sub-committee on street lighting has prepared, on behalf of the National Committee, a memorandum on the subject for submission to the departmental committee.

The financial position of the Committee is satisfactory—income being slightly in excess of expenditure. The Committee is under considerable obligations to the Institution of Gas Engineers, the Institution of Electrical Engineers and the Illuminating Engineering Society, for their continued financial support which alone makes possible British participation in the work of the International Commission on Illumination.

The Committee again is pleased to express its indebtedness to all those gentlemen and organisations, too numerous to mention individually, who have devoted so much time and energy to the furtherance of the work of the National Committee and its sub-committees.

K. EDGCUMBE, *Chairman.*
H. BUCKLEY, *Secretary.*

Literature on Lighting

(Abstracts of Recent Articles on Illumination and Photometry in the Technical Press)

(Continued from page 86, March, 1935)

I.—RADIATION AND GENERAL PHYSICS.

104. A Precision Radiation Integrator.

R. H. Müller and G. E. Shriven. Rev. Scient. Instruments, 6, pp. 16-21, January, 1935.

The condenser-photoelectric cell method of radiation integration has been investigated. The result is an instrument capable of integrating light of fluctuating intensity to three parts in 1,000. F. J. C. B.

105. Averages of Bright Sunshine in the British Isles.

(Air Ministry, M.O. 377; H.M. Stationery Office, 1934.)

The records cover the period 1901-1930, and apply to 172 different stations—for most of which records for a period of twenty years or more are now available. The average annual duration of recorded sunshine is shown to vary greatly from over 1,800 in the Channel Isles, and on the South Coast of England to under 1,100 hours in the Shetlands and in certain industrial areas where heavy smoke pollutions occur. J. S. D.

II.—PHOTOMETRY.

106. Regulations for the Photometry of Electric Lamps with Notes on the Use of the Ulbricht Sphere.

Das Licht. p. 34, February, 1935.

These regulations have been drawn up and approved by the D.L.T.G. (German Ill. Eng. Soc.) and aim at standardising the method of testing the output of electric lamps. Both visual and objective methods of making the measurements are discussed, and the requirements set out. Details also are given for suitable coatings for the inside of the Ulbricht Sphere. S. E.

107. Practical Tests with the Ulbricht Sphere, employing new Measuring Methods.

H. J. Helwig. Das Licht, p. 33, February, 1935.

A comparison is made between the results of measurements on a series of light sources in a standard Ulbricht Sphere of 1.5 m. in diameter, and an aluminium cube with a 70 cm. side. The inner surface of the aluminium box was matted by sandblasting. The range of variation in the results was rather greater with the aluminium box than with the standard sphere. S. E.

108. A Photoelectric Photometer.

Anon. J. Sci. Inst., 29, January, 1935.

This photometer has been designed solely for spectrophotometric measurements. It can be used with almost any type of monochromator, and if suitable photo-cells (gas filled type) are fitted, it can be used for any range of wavelengths from 1,850 to 12,000 a.a. S. E.

109. Photometry and Energy Distribution of the High Intensity Mercury Lamp.

L. B. Johnson. J. Opt. Soc. Amer., 22, pp. 36-38, January, 1935.

The author points out that the luminosities produced by the high intensity lamp and those produced by a low pressure standard mercury lamp may be compared for the individual lines by placing "monochromatic" filters between the eye and the eyepiece of the photometer and balancing the resulting fields. The relative line intensities of the standard lamp have first to be determined. The method is stated to avoid errors due to subjective colour differences still apparent when filters are used with an incandescent standard. The types of filters and the results of measurements of certain high pressure mercury lamps are given. F. J. C. B.

110. Errors in Reflectometry.

A. H. Taylor. J. Opt. Soc. Amer., 25, pp. 51-56, February, 1935.

Some of the commoner sources of error in reflectometry as now practised have been analysed and their effects computed. F. J. C. B.

111. Definition of Technical Light Quantities.

H. Bertling. Licht u. Lampe, 24, p. 77, February, 14, 1935.

Discusses the limitations of the new definition for light current. "The light current of a light source is the power radiated by it, estimated according to the international eye-sensitivity curve determined for the brightness-adapted eye," proposed by the "Signs, Symbols, and Units" group of the D.L.T.G. E. S. B.-S.

112. Regulations for the Evaluation of Measurements of Colour.

Das Licht. p. 37, February, 1935.

Details are given of a standard system of colour measurement based on the I.b.E. system. Details of filters and solutions for varying the apparent colour temperature of the light are given. S. E.

113. The Evaluation of Glare from Motor Headlights.

W. S. Stiles and C. Dunbar. D.S.I.R. Illumination Research, Tech. Paper No. 16, H.M. Stationery Office, 1935.

A method is developed for determining the reduction in a driver's ability to see objects on the road ahead, due to the glare from headlights of passing cars. Due weight is given to the various influential factors in establishing a figure of merit for any headlight system. Amongst the devices of beam-distributions examined were (a) a simple headlight employing no anti-dazzle device, (b) a dipped and swivelled headlight, and (c) a headlight giving a flat-topped beam. J. S. D.

III.—SOURCES OF LIGHT.

114. The Biplane Filament in Spotlighting.

G. Mili. J. Soc. Mot. Pict. Eng., 22, pp. 131-141, 1934.

The system of two parallel rows of coils placed so that the coils in one plane fill the gaps between the coils in the other, has proved so desirable for projection that its value for spotlighting has been tested. Results are given showing the increased uniformity of the spot and the higher intensities attained.

(Photog. Abs.) F. J. C. B.

115. The Characteristics of Gaseous Conduction Lamps and Light.

L. J. Buttolph. Am. Illum. Eng. Soc., Trans. 30. pp. 147-177, February, 1935.

The fundamental principles of practical discharge lamps are described. Data are also given on their spectral emission, efficiency, and light distribution

G. H. W.

116. The High Pressure Mercury-Cadmium Vapour Lamp, a Metal Vapour Lamp for General Illumination.

H. J. Spanner. Am. Illum. Eng. Soc., Trans. 30. pp. 178-189. February, 1935.

After a discussion of the desiderata of a light source

for general lighting, details of the mercury-cadmium discharge lamp are given G. H. W.

117. New Type of Gas Lamp.

Gas World. February 23, 1935.

A description with data of a new type of high pressure gas lamp. Polar curves are given of two units which have already been designed and used. J. G. C.

118. Magnesium Light.

J. A. M. van Liempt and J. A. de Vriend. Rec. Trav. Chim., 53, pp. 839-846, 1934.

The emission of light by burning magnesium has been studied quantitatively. The efficiency of light produced was found to be 28 lumens per watt. Spectroscopic data and the rate of consumption are given.
(Photog. Abs.) F. J. C. B.

119. Zirconium Light.

J. A. M. van Liempt and J. A. de Vriend. Rec. Trav. Chim., 53, pp. 895-898, 1934.

Results obtained showed that the efficiency is 36 lumens per watt and the rate of combustion slower than that of magnesium. (Photog. Abs.) F. J. C. B.

IV.—LIGHTING EQUIPMENT.

120. The Blohm Globe.

W. Voege. Das Licht, p. 22, February, 1935.

The Blohm globe has been designed to render the distribution of light from a gas lamp more suitable for street lighting purposes. It consists of a clear glass ring surrounding the mantles, closed by an inverted cone of opal glass. Some globes also have an opal band above the ring of clear glass. Typical light distribution curves from lamps with ordinary clear globes and the same lamps with Blohm globes are given. S. E.

V.—APPLICATIONS OF LIGHT.

121. Light and Architecture.

Am. Illum. Eng. Soc., Trans. 30, pp. 139-146, February, 1935.

Illustrated descriptions of seven modern lighting schemes. G. H. W.

122. New Lighting Installation at the Metropolitan Opera House.

J. Buchter and A. L. Powell. Am. Illum. Eng. Soc., Trans. 30, pp. 210-222, February, 1935.

A summary is given of the requirements for the stage lighting in an opera house. The new equipment at the Metropolitan Opera House, New York, with its elaborate Thyratron control is described in detail. G. H. W.

123. Church Lighting.

Gas World. March 2, March 9, 1935.

An illustrated description (March 2) of a new gas lighting installation in an old Norman Church at Grouville, Jersey.

A description with illustrations of the floodlighting by gas units of Holy Trinity Church and the Esplanade Gardens, Exmouth (March 9), is also given. J. G. C.

124. Lighting Requirements of the German Road Transport orders of May 29, 1934, and September 29, 1934.

Das Licht. p. 31, February, 1935.

Some further details of the requirements and limitations imposed on the lighting of motor cars, etc. S. E.

125. Street Lighting with Gas.

Gas Times. March 9.

Description, illustrations, and data are given of a special installation of gas street lamps in Derby. An account is also given of experiments in Paris with a new type of gas-lighted beacon, including refuge bases.
J. G. C.

126. Sodium Vapour Lamps as Guiding Light with Fog.

Licht u Lampe. 24, p. 126, February 28, 1935.

Description of a sodium vapour lamp installation on the Zürichsee-Fähre for guiding ferrys during fog.
E. S. B.-S.

127. Practical Tests with Mercury Vapour Lamps for Street Lighting in Berlin.

E. Gehrmann and J. Rieck. Das Licht, p. 21, February, 1935.

An experimental installation of fifteen mercury vapour lamps in a Berlin street is described. Details are given of the illumination obtained on a section of roadway between two lamps in staggered formation, the mounting height being 9 m., width of road 14.6 m., and spacing 24.36 m. S. E.

128. Applications of the New Gaseous-Conductor Lamps.

Ward Harrison: Am. Illum. Eng. Soc., Trans. 30, pp. 190-200, February, 1935.

The paper states that a simple lamp of 40 lumens per watt in the 60 w. size or smaller appears as far off as ever. The application of the larger discharge lamps to street lighting is discussed and data are given on various applications of the high pressure mercury lamp, with and without additional filament lamps. Some preliminary results of experiments on the $\frac{1}{4}$th scale model street are given. G. H. W.

129. The Lighting of Railways.

Th. Wagner. Das Licht, p. 25, February, 1935.

A continuation of the paper given to the D.L.T.G. at Essen on September 18, 1934. This section deals with signalling, and discusses the advantages of luminous signals. S. E.

130. Floodlighting.

Anon. Elect., 114, p. 313, March 8, 1935.

Photographs showing various buildings in Sydney, N.S.W., floodlighted on the occasion of the recent Royal visit are given. C. A. M.

131. Floodlighting.

Anon. Elect., 114, p. 220, February 15, 1935.

A brief description is given, with a photograph, of a floodlighting installation in which both electric discharge lamps and tungsten lamps are employed. C. A. M.

132. Electric Floodlighting at Sydney.

Anon. El. Times, 87, p. 283, February 28, 1935.

A set of photographs of floodlighting effects produced at Sydney on the occasion of the recent visit of H.R.H. the Duke of Gloucester. W. R. S.

133. Floodlighting of a Swimming Bath with Gas.

Gas Times. March 9, 1935.

Description, illustration, and data of the floodlighting by gas lamps of a swimming-pool at Nottingham, which has a capacity of nearly one million gallons of water, and is stated to be the largest in England. J. G. C.

134. Jubilee Illuminations.

Anon. Elect., 114, pp. 308-312, March 8, 1935.

A description is given of the outdoor decorative lighting in London at the Coronation in 1910, together with details and photographs of equipment now available for the Jubilee celebrations. C. A. M.

135. Jubilee Illuminations.

Anon. El. Times, 87, p. 205, February 14, 1935.

An account of preparations being made in London and the Provinces in connection with the Silver Jubilee celebrations. Many photographs are given. W. R. S.

136. Irradiation of Milk.

Anon. Elect., 114, p. 209, February 15, 1935.

The ultra-violet radiation from a 3,000 w. arc lamp is used in California to increase the vitamin D content in milk. A photograph is given. C. A. M.

Recent Patents

(Abstracts of recent Patents on Illumination & Photometry.)

No. 422,859. "Improvements in or relating to Electric Lamp Mountings."

A. Reyrolle and Company, Limited, and Tiplady, J., July 20, 1933.

This specification relates to flame-proof electric light mountings for use in mines and the like where there may be an explosive atmosphere. The lamp bulb is surrounded by a metal gauze screen, and the latter is enclosed by a cover of translucent diffusing material which prevents sharp shadows being cast by the gauze.

No. 422,912. "Improvements in Miners' Safety, or like, Lamps and Protecting Guards for same."

Hailwood, E. A., June 22, 1933.

This specification relates to protective guards for miners' safety lamps of the kind provided with guards in connection with the bonnets. A skeleton guard formed from one piece of suitably shaped material is attached to the outer frame of the lamp so as to be spaced from the bonnet and to provide a minimum of contact with the lamp. The guard may be shaped to the configuration of the wearer's body, and its point or points of contact with the lamp may be provided with heat-insulating material.

No. 423,049. "Improvements in or relating to Electric Incandescent Lamps with Internal Reflectors."

"Lampe Yvel" Auto-Lampe et Cie, Anciens Establissements Leo Levy et Alfred Monnier, August 8, 1932 (Convention, France).

This case covers a reflector, for mounting within the envelope of a motor car head-lamp or like bulb, of which the section normal to the longitudinal axis is essentially V-shaped, the limbs forming an angle exceeding 90° and preferably about 105°. The reflector is particularly suited to bulbs having two filaments.

No. 423,132. "Improvements in Light Filters."

The General Electric Company, Limited, February 24, 1933 (Convention, Germany).

This application relates to light filters particularly for screening or enveloping incandescent lamps to pass a spectral band particularly favourable to the human complexion. The filter, which is said to be relatively cheap, comprises a compound of neodymium or the like and so much light scattering material of such quality that the quantity of light absorbed by the neodymium or similar compound is substantially greater than it would be in the absence of the scattering material.

No. 423,142. "Apparatus for producing Moving Illuminated Signs."

Aroldo Chiti, April 3, 1933 (Convention, Germany).

This specification describes a moving letter or like luminous sign in which the moving sign is formed by perforations in an opaque travelling band. The light transmitted through the perforations is optically projected upon a screen consisting of a large number of contiguous double convex lenses which may be formed by crossed hemicylindrical rods. The screen, as a whole, may be corrugated or angulated.

No. 423,214. "Improvement in and relating to Electric Signs."

Hollands, W. M., May 3, 1934.

This specification relates to traffic control and like electric signs for exhibiting alternative signals. The sign comprises a casing having a front opening, a light source behind the opening, and a transparent reflecting device, e.g., a thinly silvered mirror, obliquely disposed between the opening and light source, a second light source disposed so that its light may be reflected through the opening, and a grid, composed of horizontal slats spaced apart, in the front opening to restrict the entry of external light into the casing. Alternative signals may be exhibited by illuminating one or other of the two light sources, which may be provided with stencils or the like for this purpose.

No. 423,355. "Improvements in Luminous Signals for Controlling Street Traffic."

Curran, E., April 26, 1933.

According to this specification, in a luminous signal of the type in which various coloured beams are projected successively through a translucent drum rotatable about a vertical axis, the drum is provided with two or more separate chambers enclosing sources of light from which indicating beams are successively emitted during a portion of each revolution, the rotation causing a gradual reduction of the arc of each emitted beam.

No. 423,362. "Improvements in or Relating to Luminous Tube Signs or Designs Operating by High Frequency Currents."

Warner, A. R., July 25, 1933.

According to this specification, a luminous tube sign energised by a variable radio frequency voltage has, disposed close to it, a capacity area connected to the energising circuit. The capacity area is distributed so that the luminosity commences at one end of the tube and spreads along the tube. The capacity distribution may be non-uniform along the length of the tube.

No. 423,464. "Improvements in Light Reflectors."

Leray, G., December 31, 1932, March 28, 1933 (Cognate, Convention, Germany).

This specification relates to reflecting elements capable of being assembled to form a reflector of which the surface is not discontinuous. The element may comprise a plane base, an opposite area made up of three planes intersecting each other at right angles and having an apex disposed perpendicularly over the centre of symmetry of the base, and remaining areas consisting of four planes at right angles to the base and each at right angles to the two adjacent planes. Two of the four planes may be replaced by portions of co-axial cylinders, and the other two may be inclined to each other so as to intersect in the axis of the cylinders. One of the planes of the area opposite to the base may be replaced by a convex surface.

Comparison of the Revealing Powers of White & Coloured Headlight Beams in Fog

By W. S. STILES, Ph.D.
(The National Physical Laboratory).

SUMMARY.

This paper gives in full the results of experiments undertaken by the Department of Scientific and Industrial Research, to discover whether the range at which objects can be seen in headlight beams in fog is increased by the use of a suitable colour filter. Colour filters, giving red, orange and blue-green beams, were tried, for conditions of slight and thick fog. It was found that for a neutral object no increase of range could be obtained by the use of a colour filter. The observed change in range was either negligible or a small decrease. The effect of a colour filter on range was found to be the same as that obtained by substituting for the colour filter a neutral filter of the same total transmission.

1. Statement of the Problem.

In September, 1931, the International Commission on Illumination passed a provisional resolution stating that there was no advantage to be gained by using coloured headlight beams in fog. Subsequently this resolution was withdrawn, partly because the evidence in favour of the statement was indirect and of too vague a character. As a result of the interest of the National Illumination Committee of Great Britain in this question, an investigation, sponsored by the Illumination Research Committee, was undertaken at the National Physical Laboratory to discover by direct observations in fog whether objects could be picked up at greater distances using coloured headight beams than with white. The present Report gives an account of the experiments made and of the results obtained.

In practice, coloured headlight beams are always obtained by placing certain colour screens or filters in the path of the rays issuing from a headlight, of which the primary source is an incandescent electric lamp emitting white light. The beam becomes coloured because the absorption of the colour screen is different in different parts of the spectrum, e.g., if the absorption is much higher in the blue end of the spectrum the beam is changed from white to yellow. Since the colour screen acts by absorption the change of colour is always accompanied by a reduction in the intensity of the beam. Now if there is an increase in revealing power in fog when the colour screen is inserted, other conditions remaining unchanged, this might be due, not to the change in colour, but to the reduction in intensity. Thus the two questions calling for answer are:—

(1) does the interposition of a colour screen of some suitable absorbing properties improve the revealing power of headlights in fog?;
(2) if so, is the improvement due to the change in colour or to the reduction in intensity, or in part to both?

It is, of course, assumed that the interposition of a colour screen or neutral filter leaves unchanged the angular distribution of candlepower in the headlight beam.*

The answer to question (1) can be obtained by comparing the revealing power with and without the colour screen. If increased revealing power is obtained with the colour screen, or if there is an effect in the opposite direction, further experiments can be made to compare the revealing power given by the colour screen, with the revealing power obtained by replacing it with a neutral screen or filter which reduces the luminous intensity† of the beam by the same amount. If the neutral screen and the colour screen yield the same revealing power, then the effect of the colour screen is merely due to the accompanying reduction in intensity. In this way, the answer to question (2) can be obtained.

It remains to find a method for assessing revealing power. The simplest procedure is to determine the maximum distance away of a specified test object at which the driver can just detect its presence. Calling this distance the range, we may treat range as a quantitative measure of revealing power. The experiments on revealing power described in this Report, are in reality determinations of range, and the conclusions drawn apply to revealing power as measured by range and not necessarily to revealing power assessed in any other manner.

2. Experimental Method and Apparatus for Range Measurements.

The immediate object of the experiments was to determine the distance between a certain test object and the headlights at which an observer in the position of the car driver could just detect the presence of the object. The difficulties of determining ranges for an observer in a moving car led to the adoption of the following static method: Two 8-in. diameter headlights were mounted on a wooden truck, at a height of 2 ft. 9 in. above road level, and spaced 2 ft. 6 in. apart. These distances were chosen as representative of the positions of the headlights on the commonest types of car. The truck was wheeled into position on a stretch of roadway (Kelvin Avenue) in the N.P.L. grounds, and placed so that the headlights, adjusted with their axes horizontal, pointed along the road, with the offside headlight displaced laterally 9 ft. from the kerb (measured on the road surface). The observer took up his stand behind the offside headlight and at a distance from it of about 2 ft. 6 in. As the observer stood on the road, his eye height equalled about 5 ft.

The test objects used in most of the work consisted of wooden discs 1 ft. 6 in. in diameter, each mounted on a wooden upright, so that the centre of the disc occupied a point 2 ft. 9 in. above the road surface. Each disc was painted with a mixture of

* In some practical devices, this is not the case, but here we are only concerned with effects arising from a change in the colour of the beam.

† In assessing the relative luminous intensities of white and coloured headlight beams, the established methods of heterochromatic photometry must be used

black and white paint, discs of different reflection factor from 5 per cent. upwards being obtained by adjusting the proportions of black and white in the mixture. In general, the test discs were placed on the road, so that the centre of the disc lay on the axis of the offside headlight (disc position A), with the surface of the disc inclined to the headlight axis at an angle of about 45°. The discs were inclined in this way to avoid the specular reflection of the headlight beam into the observer's eyes. To facilitate the determination of the distance of the disc from the headlights, a measuring tape was laid along the road vertically below the axis of the offside headlight. As the disc stand rested on the

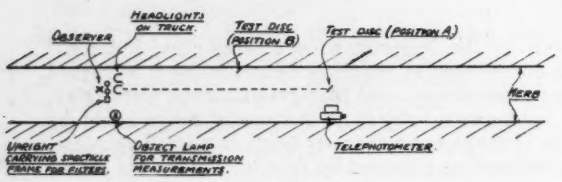


Fig. 1.

tape, the disc distance could be read off directly. Fig. 1 shows in plan the general arrangements of headlights, test disc, etc.

In making a measurement of the range of a particular disc, an assistant placed the disc at a reasonable distance, and the observer called out whether he could see it or not. The assistant then placed the disc at a new distance, the observer looking away meanwhile, and the observation was repeated. In general, with judicious placing of the disc, from five to ten observations of this kind were adequate to fix with sufficient accuracy the position at which the disc was on the limit of visibility. It should be noted that the observer was aware of the approximate position in which the disc would be seen, if at all, and no fixed time limit was applied within which the observer's decision had to be announced. In general, if the test disc was not seen in the first second or two, it was never seen.

In determining the range for coloured beams or white beams of reduced intensity, the colour screens or neutral filters, instead of being placed before the headlights, were placed at the observer's eyes. Placing a screen of given absorbing properties before the observer's eyes will be equivalent, as far as what the observer sees is concerned, to placing a similar screen in front of the headlights, provided no sources other than the headlights (e.g., powerful street lamps, the moon, a bright sky) lie in the field of view or contribute appreciably to the brightnesses seen by the observer. The advantage of placing the absorbing screens at the observer's eyes is that they can then be made smaller. Small screens of glass or gelatine are easier to obtain than large ones; they are more uniform, and measurement of their absorptive properties is easier. The screens actually used consisted of coloured glasses and neutral gelatine filters. A spectacle frame, mounted on an upright and adjustable in height, enabled a pair of matched screens to be held in front of the observer's eyes. The screens were sufficiently large (1.5 in. x 3 in.) to give a wide angle of view, and, as the observer was not required to carry the weight of the spectacle frame, observation was as comfortable as with the unobstructed eyes. Actually measurements of the range for the unmodified beam were also taken with the eyes applied to the spectacle frame, but with no screens inserted.

The following are the particulars of the headlights, absorbing screens and test discs used in the experiments.

(a) Headlights.—Each headlight consisted of a parabolic reflector of focal length 3.05 cm., a 60 watt line filament lamp, and an 8 in. diameter weakly diffusing front glass (" diffusa " glass). The line filament lay along the axis of the headlight and was adjusted to give a beam of minimum divergence.

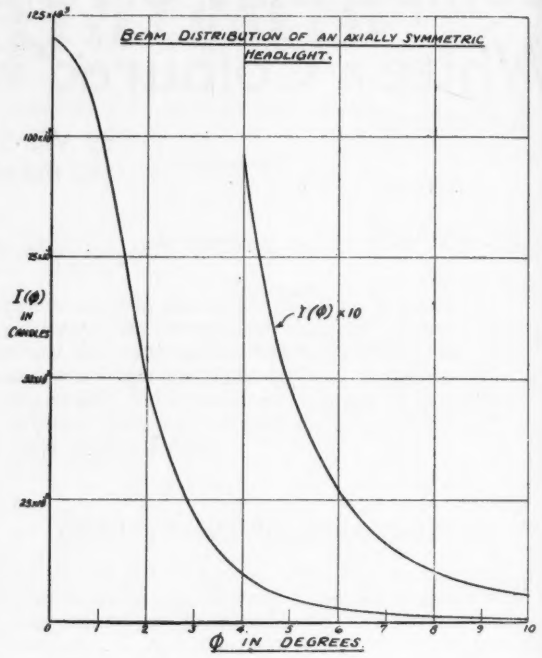


Fig. 2.

The distribution of luminous intensity in the beam was approximately that shown in Fig. 2. The candle power I at any angle ϕ ° with the axis was derived from a measurement of the illumination E produced on a plane facing the headlight at a distance of 25 ft., assuming $I = 25^2E$. Defining the divergence as the angle between the two directions in any plane through the axis, for which the intensity is reduced to one-tenth of the axial or peak value, the divergence of the headlight beams used equalled about 7.5°. The headlights were run off batteries carried on the truck. A voltmeter and variable resistance enabled the lamps to be run under steady conditions.

(b) Absorbing Screens.—Four pairs of coloured glass screens (each pair obtained by cutting in two a single piece of coloured glass) were used, which we may name light orange, dark orange, red and blue-green respectively. The transmissions of these

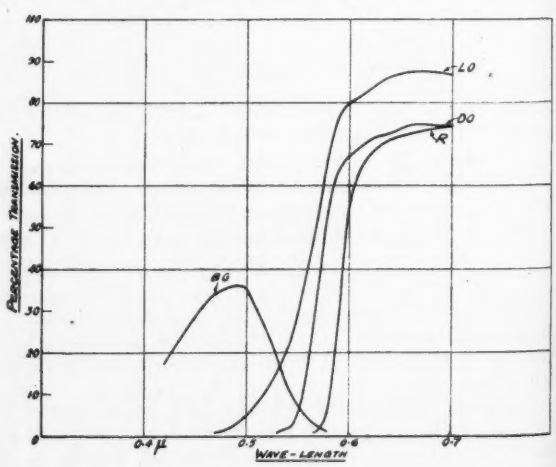


Fig. 3.

glasses throughout the spectrum measured with a spectrophotometer are shown in Fig. 3. The overall visual transmissions for light from a tungsten lamp

of colour temperature 2850°K were measured independently, using a Guild flicker photometer, and the results are shown in the following Table.

TABLE 1.

Percentage transmissions of colour screens for light of colour temperature 2850°K.

Glass	Light Orange		Dark Orange		Red		Blue Green	
Observer	Left	Right	Left	Right	Left	Right	Left	Right
W.S.S.	51.8	50.2	37.3	37.3	22.7	25.3	6.56	6.21
F.W.C.	55.0	53.6	39.1	39.5	22.8	26.4	5.48	5.15
B.O.	52.0	51.6	37.4	37.6	21.9	24.7	6.55	6.12
Mean	52.9	51.8	38.0	38.2	22.4	25.4	6.20	5.83

The colour temperature of the light given by the 60 watt 12 volt headlight bulbs is sufficiently near 2850, for the above transmissions to be taken as applying approximately to the present case. For reducing the intensity without change of colour, four pairs of neutral gelatine filters were used, whose transmissions, measured with the flicker photometer, were as follows:—

TABLE 2.

Filter.		Percentage Transmission (Mean of Two Observers).
Neutral A	Left	44.9
	Right	45.9
Neutral B	Left	19.8
	Right	20.2
Neutral C	Left	8.2
	Right	8.1
Neutral D	Left	4.21
	Right	4.91

Both for the colour screens and the neutral screens the transmissions for the left and right glasses are for our purpose sufficiently near to take a common mean value.

TABLE 3.

Mean Percentage Transmissions of Colour and Neutral Screens.

L.O.	52	Neutral A	43
D.O.	38	„ B	20
Red	24	„ C	8.1
B.G.	6.0	„ D	4.6

(c) Test Discs.—The diffuse reflection factors of the test discs measured under conditions of illumination and view approximating to those actually employed are given below.

TABLE 4.

Test Disc. No.	Diffuse Reflection Factor. Approximate Value.
0	80 per cent.
4	40 „
2	14 „
6	8 „
5	8 „
7	5 „

3. Character of the Fog.

Since the conclusions from the range measurements might depend on the density or other properties of the fog, it was desirable to make determinations of the fog characteristics concurrently with the range observations. The main optical properties of a homogeneous fog are: (1) the extent to which the direct light from a source is reduced; (2) the amount and angular distribution of the light scattered by a volume element of the fog. Some tentative experiments were made to follow variations in the second of these factors, but attention was mainly concentrated on determining the transmission factor of the fog for direct light.

The transmission measurements were made with the N.P.L. telephotometer. A light source (a 40-watt 100-volt Argenta, a 1,000-watt 100-volt steriopticon or a pointolite) was set up near the headlight carriage, and was viewed by the telephotometer from a position on the roadway at about the distance away corresponding to the range observations. (See Fig. 1.) Thus the transmission measurements were made over approximately the same section of fog as was involved in the range measurements, care being taken that the light from the headlights did not interfere with the transmission measurements, or the light from the transmission source interfere with the range measurements. By inserting in the telephotometer coloured glasses similar to those employed for the range observations, the transmission could be determined for light of the colours used, as well as for white light.

Details of the telephotometer and the method of measuring atmospheric transmission with its aid need not be entered into here, except with regard to one point. The telephotometer receives and counts as transmitted light not only the direct light from the source which falls upon the object glass, but also any light incident on the object glass and emanating from the illuminated fog contained within the external field of the instrument. As viewed from the position of the telephotometer, the source appears as though superposed on a background of variable brightness.

In the case of dense fog the scattered light may constitute an appreciable proportion (e.g., 10 per cent.) of the total light collected by the telephotometer. A correction was made for this effect, by determining the scattered light intensity when the telephotometer was slightly diverted until the light source lay just outside the external field of the instrument. Since the scattered light intensity decreases as the telephotometer is turned from the direction of the light source, the correction obtained in this way will be too small, i.e., the corrected transmissions will tend to be somewhat larger than the true values.

The transmission measurements served in the first place to specify approximately the degree of fog for a given series of range measurements, and, secondly, to follow fluctuation in the fog during each run.

4. Details of the Experiments.

The observations recorded were made on a series of six nights in the period November, 1933, to January, 1934. Forecasts obtained from the Air Ministry, Meteorological Section, were very helpful in indicating whether fog would develop after dark, and whether day fog would persist. The range determinations for different filters were made, as a rule, in the following order: Open—L.O.—A—D.O.—R—B—C—BG—D—Open. Here by "open" is meant an observation with no filters interposed at the observer's eyes. Apart from the final open reading, the order used corresponds to decreasing filter transmission. During the range observations two assistants made measurements of the atmospheric transmission for white and coloured light. In some cases it was arranged that while the range for a given colour was being determined the transmission for that colour was measured. In others, repeated measurements of the transmission for white were

made throughout the whole series of range determinations. The times were noted, at which transmission readings and range determinations were made. On the average, a range determination occupied about three minutes, and a complete run (ten ranges) about half an hour.

In certain cases, the conditions of observation differed from those described in Section 2 and a few runs were made on the principle of repeated comparisons of a colour filter with the neutral filter of the same transmission. These differences in procedure are dealt with in discussing the results.

Most of the range observations were made by one observer (the writer: left eye emmetropic, right eye hypermetropic and astigmatic, corrective glass worn Y/B ratio = 1.06, colour vision normal) It would have been advantageous to make the measurements for a large group of observers, but limitations of time made this impossible. It was considered most profitable to obtain results for one observer for all the fog densities studied, rather than to obtain less complete data for each of several observers.

5. Results of Measurements.

Fluctuations in the fog density represent the main disturbing factor likely to upset the measurements. From the fog transmission measurements it was known whether for a given run the fog density had remained unchanged. In Fig 4 are shown the results of one of the best runs in regard to constancy of the

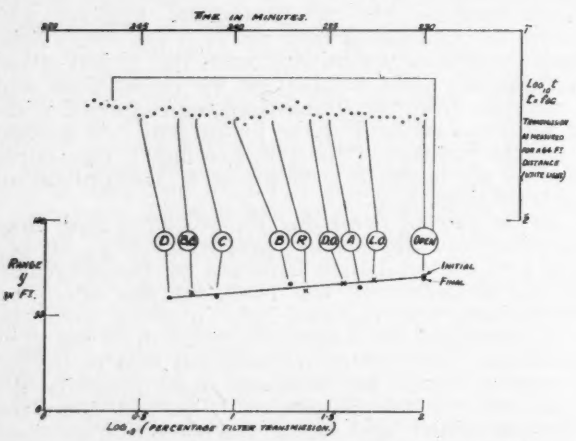


Fig. 4. Disc Reflection Factor = 80%. Run No. 27.

fog. In the lower part of the figure the observed range y in feet is plotted against the logarithm of the percentage transmission of the filters placed at the observer's eyes. (The open or no filter reading is plotted against a percentage transmission value of 100). In the upper part of the figure, the logarithm of the fog transmission t as measured for white light at a distance of 64 ft. is plotted against the time, and the straight lines drawn from the range points indicate the approximate times at which the respective range observations were made. Each value of log t is based on one photometric setting of the telephotometer and some of the scatter is due to error of measurement. Compared with other runs, the fog density must be regarded as very steady for this series. The actual fog density is high, and corresponds to a thick fog. Turning to the range observations, we observe that in all cases the range is reduced below the open value, by the interposition of a neutral or colour filter, although the reduction is small. The densest filter (transmission 4.6 per cent.) only reduces range from 70 to 60 ft. Drawing the best straight line through the neutral filter range points, it is clear that the colour filter range points lie very close to the line drawn. As far as this run is concerned, the results show no perceptible difference between the effect of a colour filter and of a neutral filter of the same transmission.

Figure 5 shows the results for a run in which the fog density decreased progressively during the measurements. It is apparent from the curves

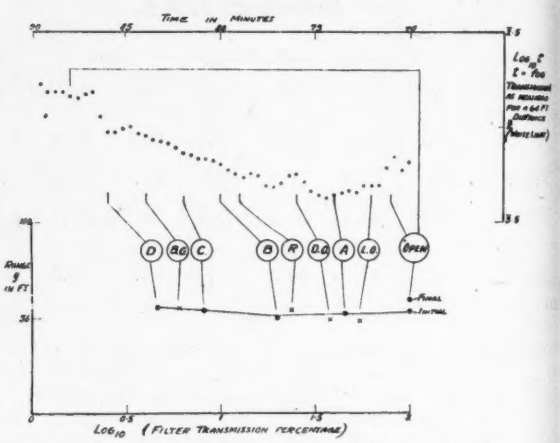


Fig. 5. Disc Reflection Factor = 40%. Run No. 28.

shown, that for this fog density range is not very sensitive to the variations in the fog transmission, although the slight rise in the range curve at the lower filter transmissions and the increase of the final over the initial open range are probably due to the marked increase in atmospheric transmission. The conclusion that a colour filter has the same effect as a neutral filter of the same transmission remains true for this run.

It was decided to apply a correction for fluctuations of the fog density for those runs for which the necessary data had been obtained. The correction was determined in the following manner. In the course of the work a number of open range values were obtained for the various test discs, at widely different fog densities. These data are plotted in Figure 6. For each test disc, a curve has been drawn

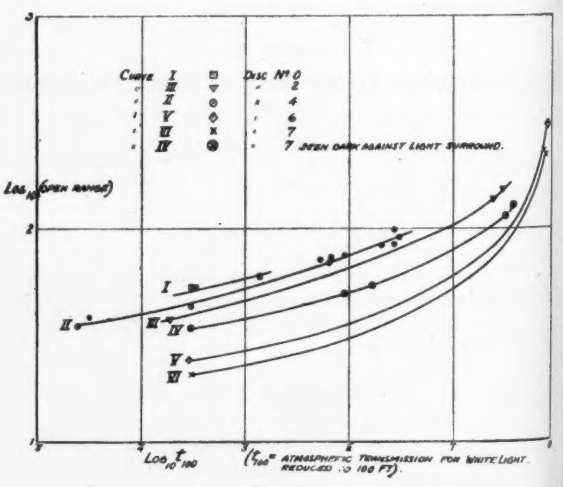


Fig. 6.

representing the variation of log range with log atmospheric transmission (reduced to 100 ft.). In the case of curves II. and IV. the plotted points determined the curve satisfactorily. Curves I. and III. have been drawn to conform in general shape with II. and IV. and cannot be much in error. Curves V. and VI have been sketched in in a reasonable manner but are not required for the present purpose. It is clear that for a given test disc the appropriate curve in Fig 6 enables open range observations in a given run to be corrected to the values which would have

been obtained if the fog had remained constant at its average density during the run. If y is the observed range measured at a time when the atmospheric transmission equalled t, then the range y_0 apropriate to the mean atmospheric transmission t_0 during the run is given approximately by $\log y - \log y_0 = k(\log t - \log t_0)$ where k is the slope of the appropriate curve in Fig 6, at the point corresponding to $\log t_0$. The variation with fog density of the ranges for the neutral and colour filters actually differs very little from that for the open ranges, and in applying the correction to determine y_0 the values of k from Fig. 6 may be used. In most cases the difference between the corrected and the observed range is small, and generally less than the scatter of the range measurements due to observational errors.

Table 5 contains a synopsis of the results for ten runs, arranged in order of increasing atmospheric transmission. The ranges for the different filters are not given directly, but instead the range ratio σ is shown, where:

$$\sigma = \text{range ratio} = \frac{\text{range with the filter}}{\text{average of initial and final open ranges}}$$

The mean values of the range ratio are plotted against the logarithm of the filter transmissions in

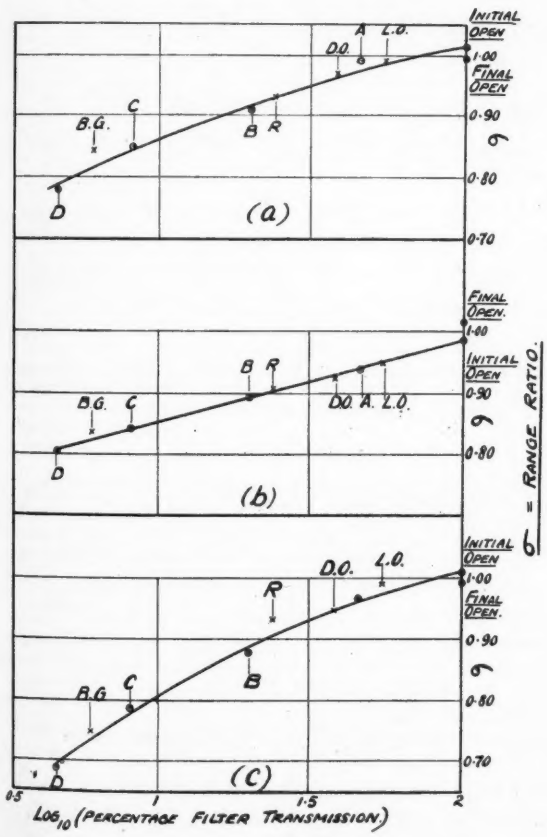


Fig. 7.

Fig. 7 (a). In Fig. 7 (b) the mean range ratios derived from the uncorrected ranges are plotted in the same manner. The difference between curves (a) and (b) is due to the fact that in most of the ten runs the fog density tended to decrease rather than increase during the run. It follows from both curves (a) and (b), (1) that the introduction of a filter, if it produces any appreciable effect, decreases the range, (2) that the effect of a colour filter on range is the same as that of a neutral filter of the same transmission. The second conclusion follows from the fact that the colour points lie so very close to the continuous curves which were drawn having regard to the neutral filter points only. The biggest deviation occurs for BG in curve (a), where the colour filter point lies 3.4 per cent. above the curve. It is doubtful whether this is sufficiently large to be significant.

Since the mean σ values were obtained from runs covering a wide range of fog densities, it is conceivable that a colour effect might occur for lower or higher fog densities which was cancelled out or diluted in taking the mean. A closer examination of the σ values in Table 5 fails to reveal any progressive change in the σ values for a coloured filter compared with those of the adjacent neutral filters, in passing from the highest to the lowest fog densities

In Table 6, the results of five further runs are summarised, for which the necessary data to apply as fog fluctuation correction are not available. The mean σ values are plotted against log filter transmission in Fig. 7 (c). All these runs refer to very slight fog, and this is apparent in the high values of the range for low reflection factor discs. The maximum deviation of a colour filter range ratio from the best curve through the neutral filter points occurs for red, for which the σ value lies 2.8 per cent. above the curve. It will be noted that with these lower fog densities a somewhat greater reduction of range results from the interposition of a filter.

On the night of November 8, 1933, when the fog was slight, several runs were made by determining alternately the range of a colour filter and the neutral filter of nearest transmission. The following were the results obtained for filters D.O. and A:

Range in feet.

Run No. 3 { Filter D.O. 269 269 270 266 302 Mean=275
" A. 269 280 258 268 277 " =270

$$\text{Ratio } \frac{\text{range of D.O.}}{\text{range of A}} = 1.01_8$$

Since the two filters have not quite the same transmission a correction is necessary, and this can be obtained applying the curve of Fig. 7 (c.). From this it appears that in the absence of any colour effect the ranges should be in the ratio D.O./A = 0.986. Thus the nett colour effect is 1.018/0.986 = 1.03.

Similar runs for other filters are summarised below:

	Observed ratio.	Ratio in absence of colour effect.	Nett colour effect.
Run No. 4.	$\frac{\text{range of R}}{\text{range of B}} = 1.04_1$	1.02_6	1.01_5
Run No. 5.	$\frac{\text{range of B.G.}}{\text{range of C}} = 0.94_2$	0.94_5	1.00
	$\frac{\text{range of B.G.}}{\text{range of D}} = 1.04_7$	1.06_4	0.98_5

In no case is the colour effect sufficiently large to be certainly significant.

6. Special Points.

The following remarks deal with special points apart from the main question at issue.

(i) Effect of Reflection Factor on Range.—It will be noted from Tables 5 and 6 that in some cases the disc was seen darker than the surrounding fog, in others, brighter. In thick fog a disc of low reflection factor, such as disc 7, appeared darker than the surrounds, when it finally vanished on increasing the distance y. When brought sufficiently close, however, every disc appeared brighter than the surrounding fog, so that for low-reflecting discs in thick fog two ranges could be determined; a near range when the disc was just too far away to be seen brighter

TABLE 5.

Run No.	Date.	Disc No.	Disc Reflection Factor (per cent).	Disc Brighter (+) or Darker (−) than surround.	Dist. for trans. measurements. ft.	$\log_{10}t_{100}$ (white light)	Average of initial and final open ranges (corrected) ft.	Range Ratio σ (Corrected) Initial Open	L.O.	A	D.O.	R	B	C	BG	D	Final Open	Remarks
25	24. 1.34	4	40	+	64	$\bar{5}.39$	35.8	1.04	0.98	1.00	0.96	0.92	0.94	0.93	0.86	0.85	0.96	
27	„ „ „	0	80	+	„	$\bar{4}.64$	53	1.03	0.98	1.08	0.98	1.06	1.01	0.96	0.99	0.97	0.97	Disc brighter than surrounds for BG & D
28	„ „ „	4	40	+	„	$\bar{3}.73$	69	1.04	1.01	0.95	0.96	0.90	0.97	0.87	0.89	0.86	0.96	
19	1. 1.34	4	40	+	121	$\bar{3}.77$	72	0.99	1.03	1.00	0.95	0.95	0.92	0.88	0.96	0.88	1.01	
20	„ „ „	7	5	−	„	$\bar{2}.02$	50	1.00	0.90	0.80	1.00	0.81	0.73	0.75	0.70	0.44	1.00	
21	„ „ „	4	40	+	„	$\bar{2}.41$	92	1.06	0.98	0.98	0.99	0.97	0.91	0.87	0.83	0.82	0.94	
23	„ „ „	4	40	+	„	$\bar{2}.45$	89	0:97	1.01	1.04	0.95	1.00	0.97	0.85	0.84	0.85	1.03	Test disc at the kerb (position B)
24	„ „ „	4	40	+	„	$\bar{2}.53$	71	0.98	0.95	0.88	0.99	0.93	0.88	0.76	0.83	0.71	1.02	
13	21.12.33	2	14	+	150	$\bar{1}.37$	120	0.99	0.99	1.06	1.00	0.91	0.92	0.90	0.84	0.81	1.01	Disc brighter than surrounds for D
14	„ „ „	7	5	−	„	$\bar{1}.53$	136	0.99	1.06	1.10	0.90	0.85	0.83	0.71	0.67	0.60	1.01	
						Mean Values =		1.01	0.99	0.99	0.97	0.93	0.91	0.85	0.84	0.78	0.99	
								Uncorrected Range Ratios.										
						Mean Values =		0.98	0.95	0.94	0.92	0.91	0.89	0.84	0.84	0.80	1.02	

TABLE 6.

Run No.	Date	Disc No.	Disc Reflection Factor (per cent.)	Disc brighter (+) or darker (—) than surround	Dist. for trans. measurements ft.	$\log_{10}t_{100}$ (white light)	Average of initial and final range ft.	Range Ratio σ Initial Open	L.O.	A	D.O.	R	B	C	BG	D	Final Open	Remarks
1	8.11.33	5	8	+			260	1.00	1.01	1.00	0.97	0.96	0.92	0.75	0.72	0.72	1.00	No transmission measurements
2	„ „ „	5	8	+			232	1.14	1.08	0.99	0.98	1:12	0.96	0.91	0.90	0.86	0.86	but estimated from range $\log_{10}t_{100}=\bar{1}.89$
10	20.11.33	6	8	+	180	($\bar{1}.94$)	270	1.00	0.96	0.96	0.92	0.83	0.83	0.82	0.76	0.67	1.00	Transmission measured at end of range observations.
11	27.11.33	7	5	+	255	$\bar{1}.91$	225	0.98	1.00	0.98	0.98	0.90	0.91	0.78	0.78	0.62	1.02	Headlights run at 8 vts.
12	„ „ „	7	5	+	255	$\bar{1}.90$	217	0.92	0.90	0.90	0.88	0.85	0.77	0.67	0.58	0.56	1.08	Headlights run at 8 vts. Observer's eye height=3.5 ft.
						Mean Values =		1.01	0.99	0.97	0.95	0.93	0.88	0.79	0.75	0.69	0.99	

than the surround, and a far range when the disc finally vanished after appearing darker than the surrounds. In Fig. 8 the observed ranges for different discs are plotted against the logarithm of the reflection factor. For discs 6 and 7 both near and far ranges were observable, for the other discs only the near range. The fog density for these measurements corresponded to $\log_{10} t_{100}=\bar{4}.47$. For very thin fogs, only the near range was observable, even for disc 7. The qualitative explanation of these observations presents no difficulty, and need not be given here.

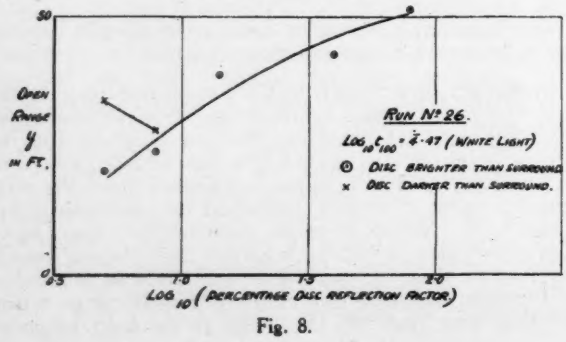


Fig. 8.

(ii) RANGE FOR A "PEDESTRIAN TEST OBJECT."—To obtain some idea of how the range for the test discs compared with that for a pedestrian on the road, on one occasion open range observations were made for five persons, who were asked in turn to walk

slowly down the beam of the offside headlight until the observer at the standard position just lost sight of them.

The following observations were made:—

Pedestrian.	Overcoat.	Trousers.	Range.	
1	Yellow	Light grey	77 ft.	$\log_{10} t_{100}$ = approx. $\bar{2}.4$
2	Black	Light grey	74 ft.	
3	Dark blue	Grey	65 ft.	
4	Very dark grey	Dark grey	57 ft.	
5	Dark navy blue	Dark blue	55 ft.	

As the hands and neck, if not covered by gloves or the upturned collar, were in general visible after the rest of the "pedestrian" had vanished, the assistants were required to put their hands in their pockets and turn up their coat collars. Comparing the above range-values with those for test discs of various reflection factors at the same fog density (Fig. 6), it is seen that these "pedestrians" corresponded to discs of reflection factor 14 per cent. or less.

A single run, made on a night of slight fog, gave the following ranges for a pedestrian in a reddish brown overcoat:—

Run No. 6.

Filter ...	Open	L.O.	A.	D.O.	B.	R.	C.	BG	D
Range in feet.	293	328	292	309	252	286	217	183	180

The results are plotted in Fig. 9. For this case the orange and red filters give ranges about 10 per cent.

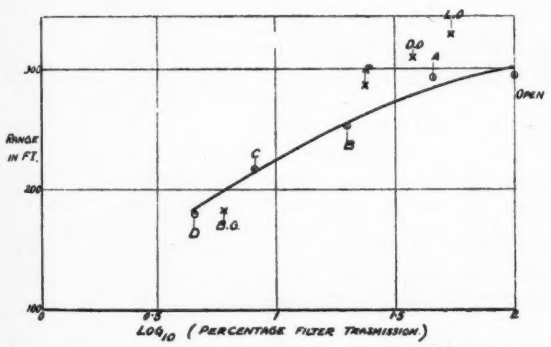


Fig. 9.

greater, and the blue green filter a range about 8 per cent. less, than those of the corresponding neutral filters of the same transmission. Thus there may be a real colour effect for this run, and in view of the reddish colour of the object this is not unlikely.

(iii) Deviations from the Standard Conditions of Observation.—For Run No. 24 the test disc was moved along a line 8.5 ft. to the nearside of the offside headlight (position B, Fig. 1), instead of along the axis of the latter. As might be expected there is a decrease of range (about 25 per cent), but otherwise the results are similar to those for the normal runs.

Two runs, Nos. 11 and 12, were made with the headlights run at 8 volts instead of 12 volts. This corresponds to a reduction of candlepower to about one-quarter. The accompanying change in lamp-colour temperature modifies somewhat the transmissions of the colour filters. The necessary adjustments have not been made, but no significant modification of the data could result. For the second of these two runs (run No. 12), the observer was seated and his eye height reduced to 3.5 ft. This meant that his direction of vision lay nearer the core of the beam and any effect of the fog (which was very slight) would be intensified. Compared with run No. 11, made on the same occasion with the normal eye height, there is, in fact, a slight reduction in range of about 4 per cent. It was thought at first that a colour effect had been obtained with the red filter, in run No. 12. An immediate repeat of the open range measurement showed, however, that the fog had lightened. The complete data for run No. 12 are as follows:—

Filter	Open	L.O.	A.	D.O.	B.	R.	Open.	R.	C.	BG.	D.	Open
Range..	200	195	195	190	168	190	225	180	145	125	121	225

In Table 6 the mean of the red filter values was adopted.

(iv.) Fog Transmissions for White and Coloured Light.—If the transmission of the fog for a distance d is measured with the telephotometer (correction for scattered light having been made where necessary in the manner indicated in Section 3), then assuming the fog to be homogeneous and of attenuation co-efficient α*

$$t = 10^{-\alpha d}$$
$$\text{or } \log_{10} t = -\alpha d$$

provided the attenuation obeys the exponential law. Thus the transmission over 100 feet is given by

$$\log_{10} t_{100} = -\alpha 100 = \frac{100}{d} \log_{10} t.$$

It will be noted that the coefficient of attenuation α is proportional to $(-\log_{10} t_{100})$. The average values of $\log_{10} t_{100}$ for white light, during the different runs, have already been given in Tables 5 and 6.

As already mentioned, measurements were also made of the transmission for coloured light, by inserting in the telephotometer colour filters similar to those used for the range measurements. Accurate comparison of the transmissions for white and coloured lights was not possible owing to the fluctuating character of the fog, and, in cases of thick fog, owing to uncertainty in the correction for scattered light. Approximate estimates from the transmission data obtained on each night could, however, be made, and we shall give the final results obtained. It is convenient to employ the ratio of the attenuation coefficients for white and coloured lights as an indication of the selective properties of the fog. If αW, αLO, αR, etc., represent respectively the attenuation coefficients for white light, light orange, red, etc., the ratios $\rho LO = \alpha 40/\alpha W$, $\rho R = \alpha R/\alpha W$, etc., will be given by:—

$\rho LO = \alpha LO/\alpha W = \log_{10} t_{100}$ (for light orange) $/\log_{10} t_{100}$ (for white light). The mean values for ρLO, ρR, etc., on the various nights, are shown in Table 7. The figures indicate no appreciable selective effect for the nights of denser fog ($\log_{10} t_{100} = \bar{1}.45, \bar{2}.24, \bar{4}.00$), but for the nights with very thin fog ($\log_{10} t_{100} = \bar{1}.94$ or $\bar{1}.91$), there appears to be a significant difference between ρBG and ρR, ρDO and ρLO in the direction of a slightly greater attenuation for blue green than for red or orange light. It is theoretically not improbable that a selective effect may be present for very thin fog but inappreciable for thicker fog.

TABLE 7

Values of the Ratios ρLO, ρR, etc., indicating the selectivity of the fog.

Date	Runs	ρR	ρDO	ρLO	ρBG	$\log_{10} t_{100}$ (white light) (Mean value)
20.11.33	10	0.79	0.95	0.85	1.08	$\bar{1}.94$
27.11.33	11 & 12	0.85	0.79	0.71	0.97	$\bar{1}.91$
21.12.33	13 & 14	0.97	1.04	0.97	1.01	$\bar{1}.45$
1. 1.34	19 to 24	1.00	0.99	1.01	1.01	$\bar{2}.24$
24. 1.34	25 to 28	1.06	1.02	1.04	1.02	$\bar{4}.00$

*The coefficient of attenuation includes the effects of both scattering and true absorption.

(v.) TRANSMISSION PROPERTIES OF HEADLIGHT COLOUR FILTERS AVAILABLE COMMERCIALLY.—Fig. 10 shows the spectral transmissions of two colour filters as supplied commercially for fitting on headlights, together with the spectral transmission of the yellow glass envelope of a motor-car headlight bulb of a type now on sale. The main claim for the use of these devices is that visibility in fog is improved. The argument advanced runs, as a rule, on the following lines, red (orange, yellow) rays are transmitted more and give less back "glare" than blue (green) rays; thus, a filter which cuts out the blue end and passes the red end of the spectrum will reduce back glare compared with the directly transmitted light and will give greater visibility than the unmodified white beam. If that were so, then, comparing the transmission curves of the three commercial colour screens with those of the filters employed in the present investigation, it is apparent that the R Filter is more effective in restricting the rays to the red end of the spectrum than any of the commercial filters, and should therefore give a greater improvement in visibility than the latter, provided any complication due to reduction in intensity is eliminated. By comparing the range for colour filters with the range for neutral filters, as was done in the experiments here described, the effect of variation in intensity is avoided, and it then appears that all the experimental colour filters give the same range as neutral filters of the same transmission. The inference is that for the fogs studied, any difference in the scattering or direct transmission between white light and any of the coloured lights obtained with the experimental filters, was insufficient to affect the range appreciably, and this conclusion will apply a fortiori to the less saturated colours given by the commercial filters.

Conclusion.

The results of the investigation may be summed up in the following statement:—

Measurements of the limiting range at which neutral (non-coloured) objects can be detected in motor-car headlight beams in fog show that the range for coloured light (orange, red, blue green) is the same as the range for white light, provided the light intensity is the same. Since, for all degrees of fog studied, the range decreased with decrease in headlight intensity, the use of a colour filter, which must reduce intensity, will necessarily decrease range, although the reduction is slight, particularly for thick fogs. Collateral measurements of the atmospheric transmission for white and coloured lights show that for the fogs studied the transmission ranged from 0.0025 per cent. to 87 per cent. for a distance of 100 ft. For the denser fogs (transmission 30 per cent., or less in 100 ft.), no appreciable selective transmission was observable, but the measurements in very thin fog (transmission about 80 per cent. in 100 ft.) showed a slightly greater attenuation coefficient for blue green than for red or orange light.

It appears from the above summary of the results of these experiments that the use of a colour screen is of no value in improving the revealing power of headlight beams in fog. A number of outstanding points requiring further experimental study still remain*, and the work will be continued as opportunity offers, but it is unlikely that any significant modification of the main conclusion will be called for.

Acknowledgments.

Acknowledgments are due to L. J. Collier and B. H. Crawford for carrying out the transmission measurements, and to other members of the Staff of the Photometry Department of the National Physical Laboratory, for general assistance.

In addition, the author desires to express his appreciation to his collaborators on the Special Sub-Committee† appointed by the Headlights Committee (National Illumination Committee), for their valued advice and comments on this work.

* See Appendix.

APPENDIX

In some further observations made during a fog for which log $_{10}t_{100}$ equalled about 0.05 (November 19, 1934) commercial colour filters whose transmission is shown in Curve 11 of Fig. 10, were used. A comparison was made between (a) the range with no filters, (b) range with both headlights screened by the colour filters, (c) range with the headlights unscreened but with the colour filter held in front of the observer's eyes. The range ratios (means for six observers) were found to be as follows:

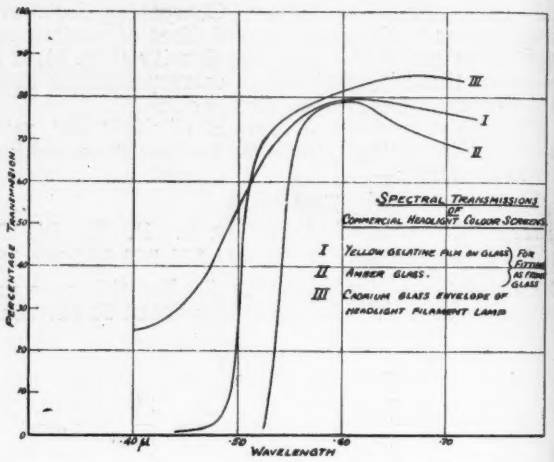


Fig. 10.

	Initial Open	Headlights Screened	Eye Screened	Final Open
Range ratio	1.005	0.994	0.982	0.997

The differences between these values are within the experimental error. The conclusion of the main Report was that no increase of range could be obtained by interposing a colour filter at the observer's eyes. Thus we now have a direct confirmation in the case of an orange filter that the same result holds good if the colour filter is placed at the headlight. The total transmission of the colour filters used was approximately 58 per cent., and it is clear from curve (a) of Fig. 7 that with this transmission no appreciable decrease in range would be expected. This is in agreement with the results given above.

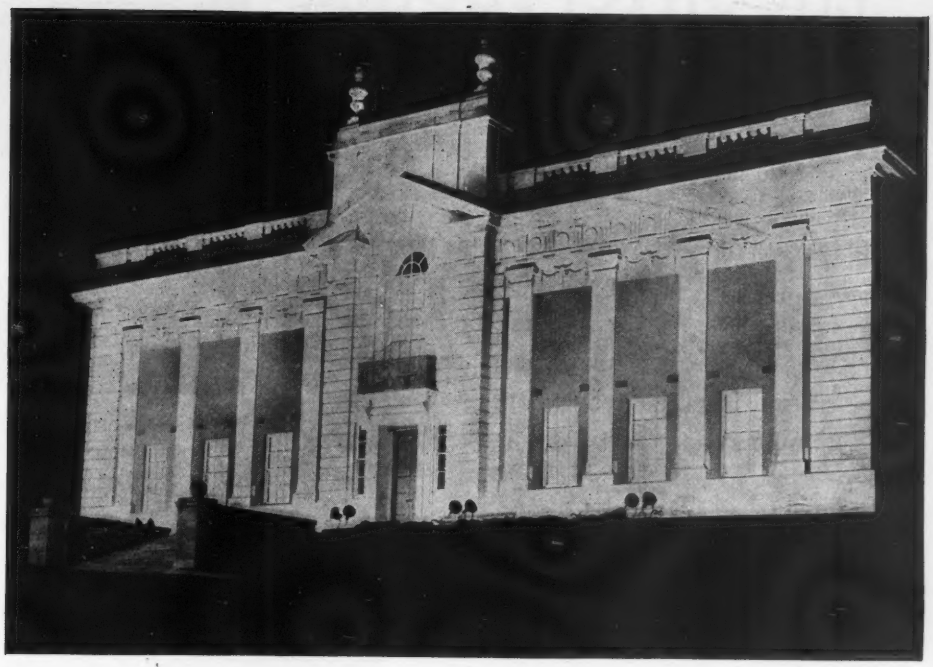
† Sub-Committee on Revealing Power of Coloured Headlight Beams in Fog, Dr. W. S. Stiles (*Convener*), Mr. M. G. Bennett, Mr. F. Newton, Dr. J. S. Owens, Mr. G. H. Wilson.

Street Lighting

We have received a copy of an informative paper on "Street Lighting," recently read by Mr. F. X. Algar before the Institution of Civil Engineers of Ireland. We hope to make fuller reference to the paper in our next issue.

DOMINATE BY

Revo



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*** HEIGHT 18 ins. DIAMETER 10½ ins. FOR LAMP UP TO 200 WATTS. LAMPHOLDER INCLUDED. BLACK EXTERIOR FINISH.**

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The Reflector in this floodlight is made of heavy gauge copper, chromium plated, and embodies a series of ribs designed to intensify the maximum light from the lamp. A sheet steel chimney housing the lampholder and easily-operated focussing device, is capped with a cast iron dome, fitted in such a way as to allow ample ventilation. The detachable rim is fitted with heat resisting glass, a cast iron base plate permits simple and rigid fixing. The unit has universal adjustment. Exceptionally light in weight this fitting is extremely useful for temporary installations on account of easy handling and transportation.

HEIGHT 18 ins. DIAMETER 12 in. FOR LAMPS OF 300-500 WATTS. LAMPHOLDER INCLUDED. ALUMINIUM EXTERIOR FINISH.

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FLOODLIGHT FITTINGS

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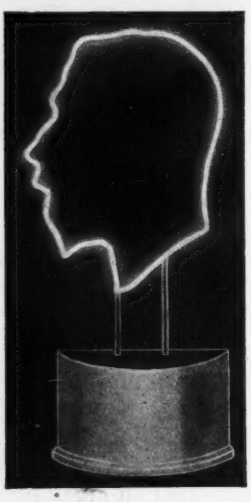
The Silver Jubilee Celebrations (1935)

In what follows we present some notes on the part to be played by lighting in the forthcoming Silver Jubilee Celebrations. We also give, by request, examples of some typical forms of equipment available to consumers for special decorative lighting.

Newark Castle Floodlighted by G.E.C. Projectors and Osram Lamps during the recent "Brighter Newark" Week.

IT is now nearly 25 years since we described in this journal the illuminations in London on the occasion of the Coronation of His Majesty King George in 1911.* The illuminations on that occasion mainly followed conventional methods, i.e., buildings were outlined in incandescent lamps or embellished with designs, executed in coloured lamps, of crowns, monograms, stars, etc. The Mansion House, the Royal Institution, and the offices of numerous insurance companies were treated in this way. The same method was adopted with gas lighting—the premises of the Gas Light & Coke Co. in the Kensington High-street, for example, were decorated with stars made up of gas-jets, outline lighting by individual burners and torches showing lambent flames.

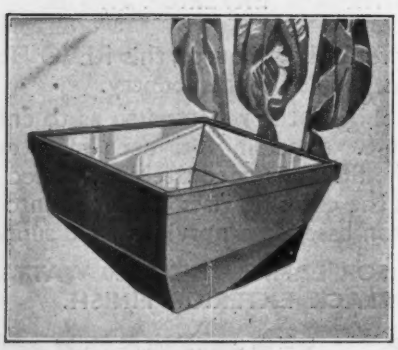
Of floodlighting, as we now understand it, there was little, though the tower of Westminster Cathedral was illuminated by concealed acetylene flares. Perhaps the best example of concealed lighting, almost resembling floodlighting in effect, was the illumination of the frontage of White's Club, St. James's-street, by the aid of a new form of Holophane strip "picture-lighting" reflector, specially designed to illuminate evenly large vertical surfaces. One other curiosity on that occasion was the use of temporary illuminated signs for the guidance of pedestrians in congested areas (stated to be used for the first time in this connection) bearing the words "Keep to the right."



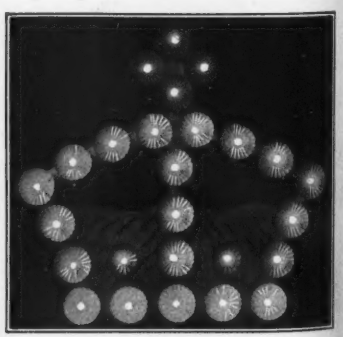
Outline of His Majesty's Head as Neon Display, consuming about 30 watts. (Falk, Stadelmann & Co., Ltd.)

The evening crowds on that occasion were considered noteworthy, but were doubtless very much smaller than the immense throngs drawn to London by the floodlighting display in connection with the International Illumination Congress (1931).

Whilst it is early as yet to announce details of the installations to be arranged next month, we understand that the display is likely to be quite as effective and probably very much more widespread than in 1931. Most of the buildings in London then floodlighted will again be illuminated. We learn, incidentally, that Holophane, Ltd., have again been experimenting with the lighting of Westminster Abbey, and that the British Thomson Houston Co., Ltd., will be dealing with Admiralty Arch, the Horse Guards Parade, the County Hall and Regent-street in London. Siemens Electric lamps and Supplies, Ltd., will be illuminating "Big Ben," St. James's Palace, the Union Jack Club (Waterloo-road), the Hall of the Society of Incorporated Accountants, etc. The General Electric Co., Ltd, will again be responsible for the lighting of Buckingham Palace and the Victoria Memorial, and there is also a possibility that they may undertake the floodlighting of St. Paul's. St. James's Park is again to receive the floodlighting with gas that was a feature



A handy ("Regent Minor") small floodlight, taking 100, 150, and 200 watt lamps. (Siemens.)



Crown made up of floral reflectors to take coloured lamps. (Siemens.)

*Illum. Eng., Vol. IV, 1911, pp. 468-476.

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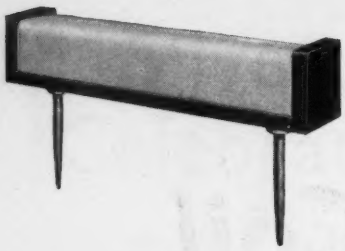


A Handy Lighting Unit for outlining flower beds, paths, etc. (G.E.C.)

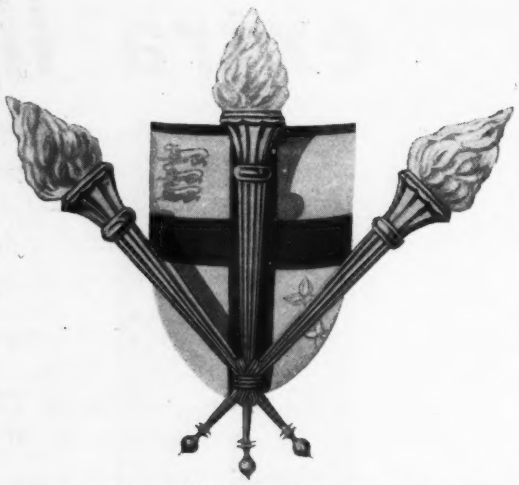
Osira Floodlighting Equipment for red, green, or blue lamps. (G.E.C.)

of the 1931 Congress; on this occasion 200 lamps will be used.

The illumination of many other London buildings is under consideration. We also hear that public buildings in many of the chief cities throughout the country are to be electrically floodlighted, and that gas floodlighting is being arranged in Edinburgh, Dundee, Manchester, Leamington and elsewhere.

Certainly the amount of floodlighting and special illumination throughout the whole country will be on an unprecedented scale. In one respect there are likely to be interesting developments as compared with 1931—namely, in the use of coloured light, which the introduction of the new electric discharge lamps so greatly facilitates.

Apart from the treatment of public buildings, premises of many large commercial organisations, insurance offices, clubs, etc., will doubtless also be illuminated. For the private consumer there are now endless varieties of devices available. We have received many catalogues from leading firms listing such devices (the G.E.C. list, with reproductions in colour, both of signs and of floodlighted buildings, is a noteworthy effort). All that is possible is to illustrate here a few typical devices. Attention may, however, be drawn to several alternatives. Apart from relatively elaborate floodlighting, which demands the use of standard projectors of certain size, there are available smaller compact units for concealed lighting which can be readily applied to illuminate a small area. Next, almost all catalogues list a great variety of medallions fitted for coloured lamps, and taking the form of crowns, portraits of His Majesty, "G.R." monograms, etc. These devices do not differ in principle much from those customary in 1911, though the technique of the lighting equipment has developed.



The "Jubcone" Shield and Flambeaux Device. (G.E.C.)

A compact Floodlight for 200 watt lamp. (Falk, Stadelmann & Co.)

The use of electric discharge lamps, as already noted, marks a radical advance. Another change, as compared with 1911, is the use of neon, as exemplified in the "silhouette portrait" of H.M. the King, here illustrated. This particular device consumes only 30 watts, and the consumption of other similar objects, crowns, monograms, etc., outlined by neon, is similarly small, so that these inexpensive decorative devices are likely to prove very popular.

The Holophane long-range projector, illustrated on page 138, is typical of equipment for floodlighting from a distance, and with a 1,000-watt lamp will furnish about 225,000 beam-candle-power. The interesting "hedralite" type, formed from a series of totally reflecting prismatic panels, is intended for close-up work. There are now available many gas lighting projectors which can do good service, though the degree of diffusion and dispersion is, in general, greater than for electric types, so that they are most easily applied when the object is not too distant nor the angle subtended too small. For fairly near work the units employing a straight line of mantles are particularly useful; some of their effects were illustrated in Mr. Bloor's recent paper before the Illuminating Engineering Society.

Other useful equipment for Jubilee lighting may be briefly mentioned. Trough fittings for coloured floodlighting and colour-changing effects, such as those developed by Holophane, Ltd., are likely to be in demand, and the so-called architectural lighting tubular lamps, now available from leading firms in a variety of colours, have great possibilities.

Laurel Wreath surrounding medallion of the King and Queen. (Franco-Signs.)

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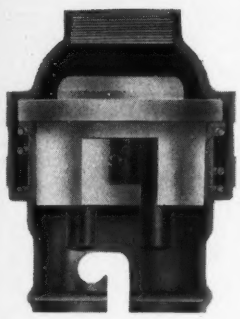

Fig. 1.
Position of socket before fitting over lamp cap.

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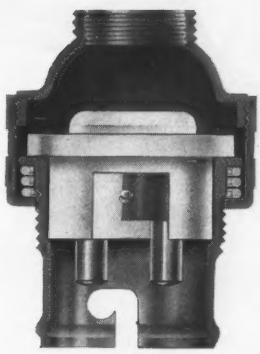

Fig. 2.
Socket drawn forward to hook over lamp cap, before locking.

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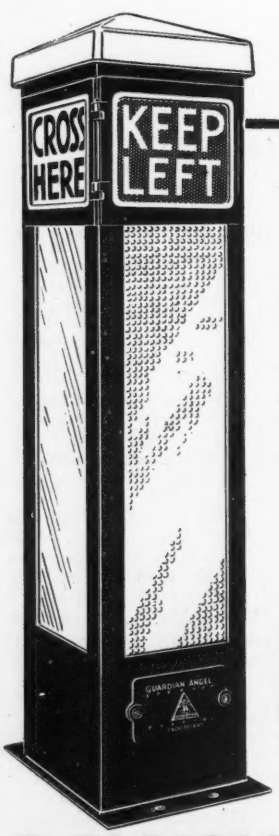
Barnsley Town Hall floodlighted by Mazda Mercra Lamps in B.T.H. Projectors.

One point may well be noted by consumers desiring to fit up a little display of their own—it is possible to hire floodlighting projectors and simple equipment from some of the leading firms—in fact there is likely to be quite a lot of this type of business available in connection with the forthcoming display.



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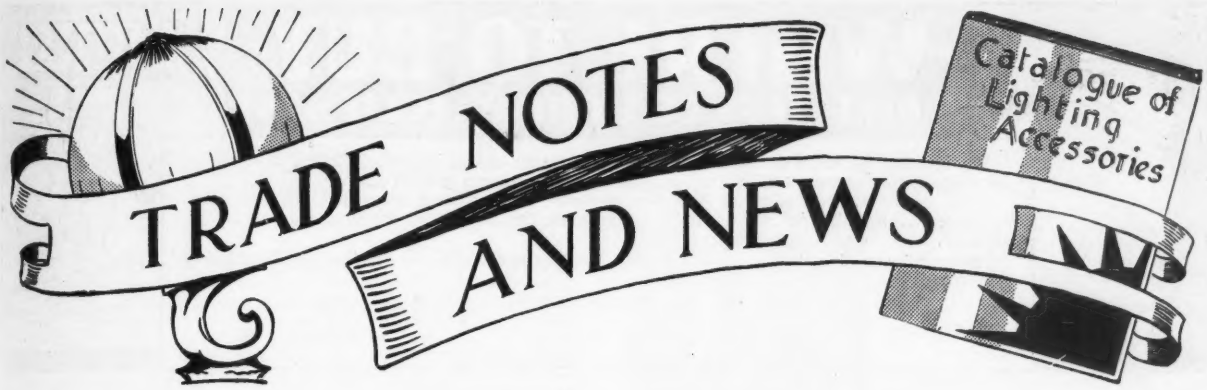

"Osira" Street Lighting at Romford

"Osira" Street Lighting has recently been installed by the County of London Electric Supply Co., Ltd., in many of the chief thoroughfares at Romford. The new installation consists of 207 Osira (400 watt) lamps housed in G.E.C. "Lewisham" lanterns. At the official switching on ceremony great appreciation with the lighting was expressed.

New Lighting at Paddington

At Paddington Goods Depot the Great Western Railway have recently installed 400-watt Siemens Sieray "W" type electric discharge lamps, with good results. The soft shadow conditions and good diffusion of light are illustrated in the picture above, and it is believed that the better lighting will materially speed-up the checking and handling of packages and diminish the number of cases of wrong loading.

Hornby Solid Contact Locking Lampholder

This ingenious lampholder, illustrated below, resembles externally the ordinary bayonet cap-holder, and is used under identical conditions. The feature which marks a departure from old designs is the internal construction. There are no spring plunger contacts. Each contact forms one solid and direct connecting piece between wire and lamp. The contacts are self-seating and even pressure is maintained by one large insulated spring in the outer casing. The lamp can only be released by pulling forward the bayonet socket simultaneously with the removal of the lamp.

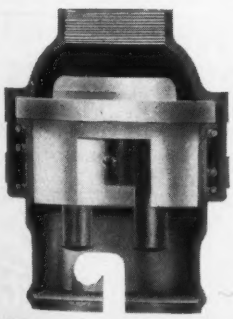

Fig. 1. Position of socket before fitting over lamp cap.

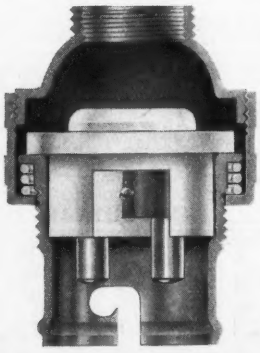

Fig. 2. Socket drawn forward to hook over lamp cap, before locking.

Holophane Recessed Dome Reflectors

A recently issued Holophane leaflet illustrates a neat fitting, the recessed dome reflectors, suitable for mounting flush with the ceiling in shop windows, etc. A new and revised edition of "Holophane Engineering Data," originally issued in 1930, has just been published. We have just one criticism of this useful compilation—the type is surely uncomfortably small!

A Gas Year Book (1935)

An enterprising departure is made in the year book issued by the Newcastle-upon-Tyne and Gateshead Gas Company, which presents the Chairman's Report and Accounts, supplemented by popular notes, in an unusually readable form. The new lighting at Whitley Bay is illustrated, and there is an article reviewing progress in the industrial field.

"The Reflector"

This bright publication of Benjamin Electric, Ltd. (February, 1935), contains illustrated notes on a number of striking installations, including those in a big radio factory at Ilford, and a shirt-making business in Gloucester. Perhaps the most interesting picture, however, is the night view of an "Autoport" station on the Glasgow road. Both the structure and the lighting are original in design.

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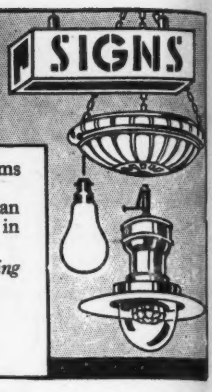

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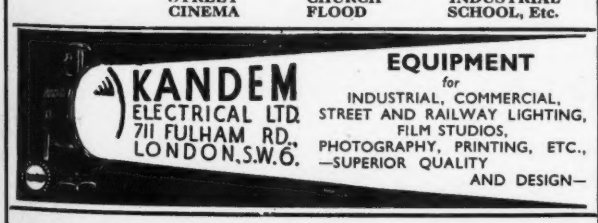

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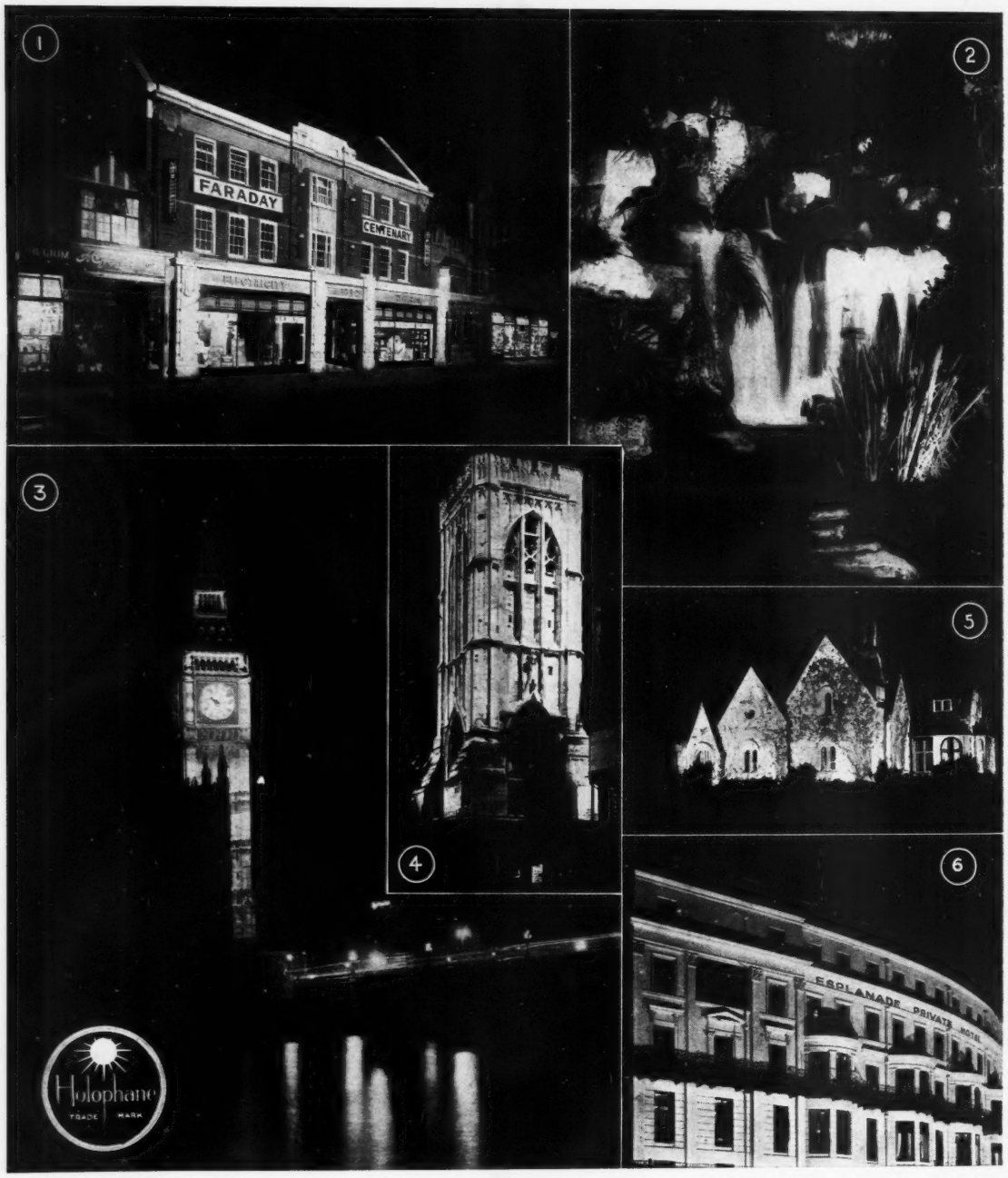

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